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Please direct correspondence to:

Dr. Eric R. Loft, Editor in Chief
California Fish and Game
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AUTUMN DIET OF CACKLING CANADA GEESE IN RELATION TO AGE AND NUTRIENT DEMAND

DENNIS G. RAVELING AND DAVID S. ZEZULAK[1]
Department of Wildlife and Fisheries Biology
University of California, Davis, CA 95616

We studied autumn foraging habitat selection by cackling Canada geese (*Branta canadensis minima*) at Tule Lake National Wildlife Refuge, California from 1985-1987. More than 91% of cackling geese foraged in barley stubble when there were relatively few (14.9%) immatures in the population (1985). In 1986 and 1987, when there were relatively large proportions of immatures (35.9% and 26.1%, respectively), cackling geese foraged predominately in alfalfa or winter wheat (96.8% of both age classes in 1986 and 61.6% of adults and 87.2% of immatures in 1987). In November 1987, irrigation flooded about 1,000 acres of potatoes and barley which attracted about 10,000 of the ±40,000 cackling geese that had been feeding in one alfalfa field. Proportionally more adults than immatures moved to the flooded barley. Alfalfa leaves and sprouting winter wheat contain about 1.9 to 2.5 times more crude protein than barley seeds, whereas barley contains about 2.2 times more carbohydrates than green forage. Immature cackling geese were in protein demanding events of growth and molt. Large numbers of immatures in the population may increase use of green forage. A poor production year may result in most geese using barley because energy requirements can be obtained in about 25% of the time required when grazing. Ample green forage for cackling geese should be provided even if the geese do not use such foods in some years.

INTRODUCTION

The estimated size of the cackling Canada goose (hereafter cackling goose) population in autumn in the Klamath Basin of California (primarily Tule Lake National Wildlife Refuge [NWR]) (41° 56' N, 121° 2' W) plummeted from more than 350,000 in the mid-1960's to fewer than 30,000 by 1983 (O'Neill 1979, Raveling 1984, King and Derksen 1986). Hunting of cackling geese in the Pacific Flyway has been closed from 1984 to the present. In an attempt to keep cackling geese in the zone of Tule Lake NWR closed to hunting of all geese, managers rejuvenated a 40.5 ha (100-acre) alfalfa field next to the roost lake and expanded plantings of winter wheat to about 162 ha (400 acres) near the roost lake between 1984 and 1987. Experience showed that cackling geese did not make heavy use of green forage in some autumns and this caused concern because of the extra resources managers had to devote to

[1]Present Address: California Waterfowl Association, Suite 200, 3840 Rosin Court, Sacramento, CA 95834

wheat and alfalfa cultivation while thousands of hectares of grain were available from leased lands on the refuge.

We recorded the foraging habitat use of individually identifiable neck-banded cackling geese from 1985 through 1987 in relation to age of individuals and population age structure. Immature cackling geese are smaller than adults (Raveling 1978) and frequently in heavy molt of juvenal contour feathers in early autumn, both of which are protein demanding events. Cackling geese preferentially select high protein green forage over seeds in spring and summer when demand for growth is high (Raveling 1979*a*, 1979*b*; Sedinger and Raveling 1984, 1986). We predicted that immatures in autumn would also select higher protein foods, whereas non-breeding adults and those geese having completed molt would better meet their daily energy demand by selecting higher carbohydrate foods such as barley seeds.

METHODS

We estimated numbers of cackling geese from the ground in early autumn on an almost daily basis to document the arrival of migrants. The U.S. Fish and Wildlife Service (FWS) flew periodic aerial surveys. We took aerial photographs in 1985 and 1986 of virtually all flocks of cackling geese within 2-7 days of when peak populations were estimated from ground counts. The flocks were usually isolated from flocks of greater white-fronted geese (*Anser albifrons frontalis*), lesser snow geese (*Anser caerulescens caerulescens*), and Ross geese (*Anser rossii*) (following the taxonomy of Delacour 1954). Even if flocks of the different species were close together or partially mixed, other species did not tolerate as close an approach by the aircraft and flew away, leaving only cackling geese to photograph. Photos were taken during midday when nearly all cackling geese were on the roost lake. The success of these photo inventories depended on the aircraft approaching at about 1,524 m (5,000 ft) above the surface of the lake and then slowly spiraling down to lower altitudes while taking care to stay outside the edges of flocks. Photos were taken continually with a 35 mm camera with 100 mm lense and K-64 film. The approach used allowed the aircraft to descend to or below 122 m (400 ft) where the best photos were obtained for counting geese. Initial lower altitude or more direct approaches usually caused the geese to flush and unusable photos for census purposes.

We recorded daily as many neck-banded cackling geese as possible with 20-60X spotting scopes, Celestron, and Questar reflective magnifying scopes. We noted time of day, flock sizes, and which fields were being used by cackling geese.

Age structure of the population was obtained from cannon-net captures or assessment of plumage differences between age classes. No cackling geese were trapped at Tule Lake in autumn 1985 so we used a sample of 345 geese trapped at Sacramento NWR (39° 27' N, 122° 5' W) between 23 December-31 January. No geese were trapped in 1986, so we estimated age structure at Tule Lake NWR based on the different appearance of breast and flank contour feathers between adults and immatures. The demarcation between the black neck and breast color is less distinct in immatures than in adults, and the flanks and breast are lighter in color and contain narrower contour

feathers with more prominent shafts than those of adults. These differences in plumage characters are similar to those reported for *B. c. parvipes* or *B. c. hutchinsii* in autumn by Higgins and Schoonover (1969).

Accuracy of using plumage criteria for assessment of age was tested in the field in 1986. We recorded the age based on plumage of a sample of cackling geese neck-banded in Alaska in 1986 and later compared our identification with age recorded at the time of banding. Of 108 such identifications, 105 (97%) were correct. The errors were 3 immatures classified as adults, probably because they were among the first hatched and had progressed in the molt cycle ahead of the bulk of the immature population.

Age-ratio data in 1987 were collected from unbaited cannon-net captures in an alfalfa field, a baited (barley) cannon-net catch in a harvested barley field, and from plumage criteria of feeding flocks in the same alfalfa field from which cannon-net captures were made. Attempts to assess age structure from plumage characteristics in both 1986 and 1987 were made only in wheat or alfalfa fields because we had a clear view of the full body of the geese that could not be obtained in stubble fields. Care was taken to sample flocks by using a series of transects from front to back of a flock under bright light conditions that best revealed plumage color differences when spacing of geese was wide enough to clearly view most individuals. Transects through the entire flock were used instead of scanning along the edge where identification was easiest because immatures were more concentrated on the edge (e.g., Owen 1972 and see below). Similarly, plumage criteria estimates were made when nearly all geese were in fields and not on the roost lake, as immatures predominated in feeding flocks during midday (see below).

RESULTS

Migration Arrival and Population Sizes

The first few hundred to 4,000 migrant cackling geese arrived at Tule Lake NWR on 15-16 October 1985 and 1986 and 22 October 1987. Major arrival and peak population numbers occurred 7-11 days later on 22 October 1985, 27 October 1986, and 1 November 1987. Peak counts of cackling geese obtained from air photos were 32,500 on 31 October 1985, 40,000 on 3 November 1986 and, from an aerial inventory, 30,000 on 4 November 1987. Migration in 1987 was unusual in that several thousand cackling geese in addition to the 30,000 estimated peak arrived at Tule Lake between 1-3 November when data on neck-banded individuals were gathered, but then moved on to the Sacramento Valley before the aerial census was conducted on 4 November. The peak populations at Tule Lake NWR represented about 70% (1985), 66% (1986), and 55% (1987) of the total population based on inventories and sightings of neck-banded individuals in other locations (unpubl. data). About 23% (1985), 24% (1986), and 29% (1987) of the cackling geese stopped in Washington or Oregon; other cackling geese migrated directly to the Central Valley of California without stopping at Tule Lake NWR.

Age-ratios

The proportion of young (14.9%) trapped in cannon-nets in 1985 was much smaller ($X^2 = 16.68, P < 0.001$) than in 1987 (27.4%) (Table 1). Age-ratios of cannon-netted, larger-bodied subspecies of Canada geese may be highly misleading (Raveling 1966). However, we believe the data from cannon-netted cackling geese caught when most of the birds were off the roost lake in feeding fields were valid indices of production because family members were not often together and adult males and families did not defend food resources as did large-bodied subspecies of Canada geese (Johnson and Raveling 1988) which resulted in large variation in age-ratios captured (Raveling 1966). An example of how misleading cannon-net catches may be in some circumstances was provided by the capture in midday when the majority of the population was on the roost lake. About 4,000 cackling geese persistently returned to the alfalfa adjacent to the roost lake that virtually all cackling geese used in the morning and evening. It was obvious from viewing plumage that the great majority were immatures and our capture at the edge of the field was made up of 94.7% immatures (Table 1). We did not use this value for estimating population age structure. This result also demonstrates how some birds were driven to feed almost constantly in this green forage. Many of the immatures feeding in midday still had down exposed on the belly that was not yet covered completely by newly erupting juvenal contour feathers.

An average of 825 cackling geese were captured annually with cannon-nets between 1955 and 1984 (total of 24,757) by W. C. Rienecker at Tule Lake NWR in early morning when nearly all the cackling geese were feeding (CDFG, unpublished data). The mean proportion of immatures in these captures was 25.2% ($R = 4.7$-48.1%). Note that estimates of age-structure in 1987 from using plumage criteria (25.6%) were

Table 1. Age-ratios of cackling Canada geese at Sacramento NWR in 1985 and at Tule Lake NWR in 1986 and 1987.

Year	Method	*n*	% immature
1985	Cannon-net	345	14.9
1986	Plumage	7,242	35.9
1987	Cannon-net		
	Unbaited in alfalfa, center of flock during a.m. feed period[a]	130	33.1
	Barley field, baited, late p.m. feed period[a]	228	24.1
	Mean of cannon-net captures[a]	358	27.4
	Plumage, alfalfa, a.m. feed period[a]	449	28.5
	Plumage, alfalfa, late p.m. period[a]	547	23.2
	Mean of plumage estimates[a]	996	25.6
	Combined mean of cannon-net and plumage estimates[a]	1,354	26.1
	Cannon-net, alfalfa, edge of flock[b]	94	94.7

[a]Essentially all geese off roost lake with single largest flock feeding in this field (more than 1/2 to nearly all used this field).
[b]Most geese were on roost lake; net was at edge of field but most geese were feeding on edge.

similar $X^2 = 0.43$, $P > 0.50$) to estimates from cannon-nets (27.4%) (Table 1) and close to the long-term average from cannon-net catches (25.2%) whereas the proportion of immatures in 1985 (14.9%) was far below the long-term average. Productivity in 1986 (35.9%) was above the long-term average, but this value was affected by the small proportion of non-breeding yearlings in 1986 from the poor 1985 production.

Foraging Habitat

When the proportion of immatures was low in 1985, more than 91% of the geese fed in barley (Table 2). Surprisingly, a slightly higher proportion of adults (8.1%) used grazing fields than did immatures (1.9%). We have no explanation of this result, but clearly a great majority of each age class fed in barley stubble. In 1986 and 1987, when production of young was much higher, most of the population used grazing fields. At times nearly all of the Tule Lake population of cackling geese would be in 1 or 2 alfalfa or winter wheat fields for all of their foraging time.

Note that over 87% of immatures but only 61.6% of adults were recorded in grazing fields in 1987. Both age-classes in 1986 used different feeding habitats in identical proportions. The result in 1987 occurred because of an unusual event. Because of drought and concern over future water supplies, lease farmers flooded about 1,000 acres of potatoes and barley (much of which was still standing) in early November. There was an immediate response by a portion of all species of geese present to shift to this newly flooded habitat for both roosting and feeding. We estimated that about

Table 2. Foraging habitat used by neck-banded cackling Canada geese during the 13-day period after the major migration arrival at Tule Lake National Wildlife Refuge, California.[a]

				Percentage of neck-banded geese recorded in:		
Year	Time period[a]	Age	n	Graze[b]	Barley	Statistic
1985	22 Oct-3 Nov	Immature	107	1.9	98.1	$X^2 = 5.41$, $P = 0.020$
		Adult	799	8.1	91.9	
1986	27 Oct-8 Nov	Immature	471	96.8	3.2	$X^2 = 0.001$, $P = 0.975$
		Adult	2,085	96.8	3.2	
1987	1 Nov-13 Nov	Immature	585	87.2	12.8	$X^2 = 122.6$, $P = 0.000$
		Adult	1,183	61.6	38.4	

[a]The time period for analyses was set to provide equal periods after the major migration arrival in each year. The analysis in 1987 was terminated on 13 Nov because public hunting for pheasants (*Phasianus colchicus*) began on 14 Nov in the areas used by cackling geese which caused frequent disturbance to feeding flocks and dispersed them to fields not used previously.
[b]Alfalfa and winter wheat.

10,000 cackling geese left the alfalfa field which virtually all of the 30,000-40,000 cackling geese used before the flooding. Interchange between the alfalfa and flooded barley fields was small compared to the numbers of cackling geese using the 2 different habitats. Our observations of neck-banded individuals demonstrated that adults were differentially attracted to the barley compared to immatures (Table 2).

DISCUSSION

Feeding behavior in wild populations is likely to vary with sex, age, and individuals, and evolved feeding specializations are likely related to food supplies, phenotypic differences, and frequency dependent pay-offs (Partridge and Green 1985). To be more specific about food supplies, we would add variation in nutritional demand related to age and seasonal variation in molt and growth of other tissues.

Cackling geese depend heavily on grasses for the protein demand and large gain in mass (37.8% for males and 52.9% for females) from mid-winter to arrival on breeding grounds (Raveling 1979*a,b*). Similarly, highly selective grazing on graminoids is essential to recovery of mass of adults and adequate growth of goslings in summer (Sedinger and Raveling 1984). Early nesting maximizes synchrony of the demands for growth with availability of some graminoids at or near their maximum protein content (up to 30%) in summer (Sedinger and Raveling 1986). Furthermore, geese may influence the quality of green forage through a fertilizer effect of their feces (Ruess et al. 1989) and intensive grazing which keeps graminoids in a rapid growth stage. The highest protein content of graminoids is near the basal meristematic tissue which provides essential amino acids (Livingston et al. 1971) such as glutamine and asparagine necessary for protein synthesis (McDonald et al. 1973). Selective grazing by geese resulting in maximizing protein content has been previously documented (Owen 1976, Harwood 1977, McLandress and Raveling 1981, Ydenberg and Prins 1981, Cargill and Jeffries 1984, Sedinger and Raveling 1986, and Ruess et al. 1989).

We conclude that selection of graminoids by cackling geese in autumn when there are large numbers of immatures is at least partly related to their high demand for protein to maximize growth and completion of molt before freezing weather halts the growth of graminoids. Arthur (1968) noted that *B. c. interior* on southern Illinois refuges used grazing fields shortly after arrival in autumn, but then turned to corn while continuing to use winter wheat. Crude protein content in immature and pre-bloom alfalfa ranges from 26.6-30.1% (dry weight) (Monson 1981) and from 24.8-34.4% (dry weight) in germinating winter wheat (Nat. Acad. Sci. 1971:723, 727) and was much higher than in barley seeds (13.4% in 6 samples from Tule Lake NWR analyzed by C. R. Ely, Univ. Calif., Davis). Sedinger and Raveling (1986) calculated that maximum growth rates of cackling goose goslings would require an overall dietary protein level of 40%, which was greater than that obtained in the wild even in the best conditions.

In contrast to immatures, adults examined from trap samples exhibited little molt and were heavier during early autumn than at any time during the winter until they gained mass rapidly in the month or so prior to spring migration (Raveling 1978,

1979*a*, 1979*b*). Starch carbohydrates (dry weight) were high (42.7% from Tule Lake samples by C. R. Ely) in barley seeds and low (19.4%) in wheat (Nat. Acad. Sci 1971:721, 723) and, presumably, in alfalfa (values not found). If there is not a demand for protein for growth of muscle tissue or feathers, then it is probably advantageous for cackling geese to exploit seeds, as their time spent meeting their daily energy requirement is reduced to about 1.8-2 hr/day in contrast to as much as 7.9-8.2 hr/day when grazing only (Raveling 1979*b*). A shorter time to meet energy and nutritional demands by feeding on seeds saves energy and permits more time for sleeping and resting at water roost sites where predation pressure is much reduced compared to when feeding in fields. For example, we observed 14 kills of cackling geese by golden (*Aquila chrysaetos*) and bald (*Haliaeetus leucocephalus*) eagles and one kill by a coyote (*Canis latrans*) in 1987, all in feeding fields and none at the roost lake.

The fact that nearly all cackling geese, including immatures, used barley fields in 1985 (Table 4) does not mean that they did not have some opportunity to graze on new growth shoots. Unusually heavy rains occurred in the Klamath Basin during September, and inspection of barley fields revealed that many waste grains had germinated. There was evidence that geese had grazed on these shoots although their density and availability was extremely low compared to a newly planted field. Giroux and Bedard (1988) reported a somewhat parallel case of differential selection of protein vs. carbohydrate foods by different age classes of greater snow geese (*Anser c. atlanticus*). *Scirpus americana* made up more than 74% of the diet of both age classes, but adults ate more rhizomes than immatures (49.1% vs. 22.8%), whereas immatures ate more above-ground stems than adults (39.7% vs. 11.9%). The adults were gaining high energy portions of the *Scirpus*; immatures probably got more protein from leaves (nitrogen not measured).

There are other reasons why geese may select different fields and habitats in different years. The gregariousness of cackling geese is extreme among geese (see Fig. 6.2 in Johnson and Raveling 1988). The first few hundred to 2,000-4,000 cackling geese that arrived at Tule Lake usually joined larger flocks of greater white-fronted geese in potato or barley stubble fields. The small bill of the cackling goose makes it almost impossible for them to efficiently dig and bite pieces of potatoes, and they soon walked or flew to adjacent or nearby stubble fields containing whitefronts. This was the pattern in 1985 when there were relatively few young. The majority of the adult population had no young and would have molted earlier than productive adults. Thus, it is likely that the former were in good physical condition and the remainder of the population may have been influenced in their choice of feeding locations in barley because that was where most of the population was feeding to meet energy demands in a short time. The first migrants in 1986 and 1987 also used stubble with whitefronts, but when the mass migration arrived they shifted to winter wheat and alfalfa for reasons suggested above.

Conditions on the Yukon Delta breeding grounds and the main migration stopover location on the Alaska peninsula (Sedinger and Bollinger 1987) may also influence foraging habitat selection at Tule Lake NWR because of variation in nutritional quality of diet during growth of gosling and molting of adults. Sedinger and Raveling (1984,

1986) found that goslings strongly selected the highest protein graminoids available, but the peak nitrogen concentration in those plants occurred within a week of the end of hatching. As a consequence, later hatching goslings had an inferior nutritional environment compared to early hatched goslings. Variation in weather, plant phenology, failures of berry crops, the timing of hatch of goslings, and freeze-up may force autumn migration earlier than optimal, dependent on progression of mass accumulation and molt. These summer events are likely to produce variation in selection of high protein or high carbohydrate diets for cackling geese in autumn as they arrive on migration stop-over or terminal wintering locations.

In conclusion, cackling geese may not always use managed green forage grown primarily for their benefit. However, in most years green forage is heavily used and may be essential in providing needed protein for immatures and, in some cases, adults. Such provisioning probably maximizes growth and molt of immatures that assists winter survival and may also lead to future reproductive benefits as adult muscle size is to some degree dependent on sufficient dietary protein during early development (Moss et al. 1984, Swatland 1977).

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IMPACTS OF CHANGING IRRIGATION PRACTICES ON WATERFOWL HABITAT USE IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

DOUGLAS A. BARNUM AND NED H. EULISS, JR.
U. S. Fish and Wildlife Service
Northern Prairie Wildlife Research Center
6924 Tremont Road
Dixon, California 95620

We used diurnal aerial census data to examine habitat use patterns of ducks wintering in the southern San Joaquin Valley, California from 1980-87. We calculated densities (birds/ha) for the northern pintail (*Anas acuta*), mallard (*A. platyrhynchos*), green-winged teal (A. crecca), cinnamon teal (*A. cyanoptera*), shoveler (*A. clypeata*), ruddy duck (*Oxyura jamaicensis*), and total ducks in each of 5 habitats. Densities of pintail and total ducks were greater in September than in other months. From October through January, density of teal and total ducks was greatest on Kern National Wildlife Refuge (NWR). Densities of ruddy duck and pintail were greatest on agricultural drainwater evaporation ponds and preirrigated cropland, respectively.

INTRODUCTION

Knowledge of duck distribution and use of various habitats is basic to an understanding of wintering duck ecology (Stewart et al. 1988). Recent evidence suggests that wintering habitat may limit certain duck populations (Chabreck 1979, Heitmeyer and Fredrickson 1981), but little information is available regarding the effects of habitat loss and degradation on wintering duck populations (Stewart et al. 1988). Nowhere in North America has there been greater proportional wetland loss and degradation than in California's Central Valley where more than 95% of the original wetland acreage has been lost (Frayer et al. 1989, Gilmer et al. 1982, U.S. Fish and Wildlife Service 1978). A significant portion of the remaining wetland area is threatened with contamination from agricultural drainwater and pesticides [Gilmer et al. 1982, Ohlendorf et al. 1987, San Joaquin Valley Drainage Program (SJVDP) 1987]. Loss of natural wetlands, escalating water costs for managed wetlands, and public awareness of the toxic effects of agricultural drainwater in evaporation ponds (Ohlendorf et al. 1986*a*, 1986*b*) have increased the importance of some agricultural irrigation practices in providing habitat for ducks wintering in the Tulare Basin that comprises the southern one-third of the Central Valley.

Public interest in agricultural water use policies and environmental concerns have caused a reevaluation of irrigation and drainwater disposal practices (SJVDP 1987). Traditional pre-plant irrigations (preirrigation) flooded large tracts of land to establish soil moisture and leach salts. This practice filled the shallow aquifer underlying the

Tulare Basin and necessitated subsurface drainage in many areas to remove shallow groundwater and reduce soil salinity (SJVDP 1987). Subsurface drains facilitate water infiltration thus decreasing the duration of surface ponding characteristic of traditional preirrigation. Alternate methods of preirrigation (e.g., sprinkler application) reduce water costs and the amount of drainwater effluent while still achieving the goals of preirrigation. Unfortunately, these alternate methods fail to create the shallow-flooded fields used by waterfowl. Furthermore, unlike the northern San Joaquin Valley which uses the San Joaquin River to dispose of its drainage, drainage in the hydrologically closed Tulare Basin is discharged to man-made evaporation ponds.

Irrigation water imports over 2 million tons of salt per year into the San Joaquin Valley exacerbating salt problems of the region (San Joaquin Valley Interagency Drainage Program 1979). As salinization increases in agricultural fields, salt intolerant crops (e.g., grains and safflower) must be replaced with salt tolerant crops (e.g. cotton) which have lower value to wildlife. Continued application of irrigation water without providing adequate drainage increases soil salinity and lowers the land's value for agriculture as well as habitat for wintering ducks.

Evaporation ponds are a major source of surface water available to ducks and shorebirds and the use of subsurface drain systems is in its infancy in the Tulare Basin (SJVDP 1987). As more land is drained, the total area provided by evaporation ponds will increase as will problems associated with trace element contamination (Ohlendorf et al. 1986*a*, 1986*b*).

The purpose of our research was to examine habitat use patterns of ducks wintering in the Tulare Basin. We compared densities of duck species among wetland types in the Tulare Basin to document duck-habitat relationships. We examined these relationships to assess the relative importance of various wetlands to wintering ducks and to consider the impact of changing irrigation practices on waterfowl distributions.

STUDY AREA

The 13,000 km^2 Tulare Basin historically served as a major concentration area for wintering ducks and shorebirds (Ogden 1988, Preston 1981). Water diversion projects eliminate natural supplies of water to the basin in all but years of above average precipitation. A former wetland, the basin is now almost completely devoted to agriculture. All remaining wetlands are artificial and we assigned them to 1 of 5 classes as follows: 1) Kern NWR consisted of about 1,200 ha of seasonally shallow-flooded wetlands principally managed to attract wintering waterfowl; 2) Hunting clubs provided about 1,400 ha of seasonally shallow-flooded wetlands managed to attract wintering waterfowl; 3) Preirrigated croplands comprised from 0 to 3,200 ha of harvested, tilled agricultural fields that were shallow flooded to restore soil moisture for germinating seeds and to leach salts; 4) Evaporation ponds increased from 300 to over 2,800 ha of hypersaline wetlands created to dispose of subsurface leachate from preirrigation activities; 5) Miscellaneous wetlands varied from about 100 to 40,000 ha of sewage lagoons, irrigation storage reservoirs, and flood water retention basins.

METHODS

Diurnal aerial surveys of all wetlands in the Tulare Basin were flown monthly from September through March, 1980-1987, by trained personnel from Kern NWR and the California Department of Fish and Game to monitor population trends among wintering waterfowl. Surveys were flown at a speed of 150 km/h at <50 m altitude along 800 m wide transects. Numbers of each waterfowl species and wetland hectarage were estimated for each habitat class. We calculated density of duck species by habitat class (total counted/total ha) for each survey. We compared mean monthly densities of the pintail, mallard, green-winged teal, cinnamon teal, shoveler, ruddy duck and total ducks. Counts of green-winged teal and cinnamon teal were combined because accurate species identification was not always possible when both species occurred together. A General Linear Models (GLM) ANOVA (SAS Institute 1985) was used to evaluate the effect of year, month, habitat, and their interaction. In this analysis, year was treated as a random variable to estimate variability for comparing among months and habitats. Thus, comparisons among years were not made.

RESULTS AND DISCUSSION

Northern Pintail

The overall GLM for effect of year, month, and habitat class was significant (F = 3.77, df = 90, 162, P = 0.0001) and explained much of the variation observed in pintail densities (R^2 = 0.676). When averaged over all months, the density of pintail differed significantly among habitats (P = 0.001). Preirrigated croplands supported the highest overall density of pintail in the Tulare Basin during the census period (Table 1). Kern NWR had the second highest density of pintails. However, a significant month x habitat interaction (P < 0.001) indicated certain habitats may be used more extensively during some months (Fig. 1). From October to January, densities on Kern NWR wetlands were similar to densities on preirrigated croplands and greater than densities on all other wetlands. During September, pintail densities were higher on preirrigated croplands and hunting clubs than on other wetlands.

Pintail were present at their highest densities (80.7 birds/ha) in September on preirrigated croplands. We believe that large numbers of pintail were attracted to these fields because of the presence of waste grains and because wetlands other than preirrigated croplands and evaporation ponds generally are not flooded until October.

Pintail accounted for 59% of all ducks observed (Table 2) and represented 56% and 89% of all ducks counted on Kern NWR and preirrigated croplands, respectively. Preirrigated croplands held the most pintail (40% of total pintail seen), followed by Kern NWR and miscellaneous wetlands (24% each), hunting clubs (8%), and evaporation ponds (4%). The historical importance of the Tulare Basin to pintail cannot be overemphasized. Mid-September aerial surveys for 1973- 1976 indicate that 26-58% of Central Valley pintail were observed in the Tulare Basin (U. S. Fish and Wildlife Service, 1978). Although the continental population of pintail declined

Table 1. Mean density (birds/ha) of wintering ducks for Tulare Basin wetlands, 1980-87.

Wetland class	Duck Species					
	Pintail	Mallard	Teal	Shoveler	Ruddy	Total ducks
Kern NWR	13.6	1.0	5.2	3.5	0.1	24.2
Hunting clubs	5.0	0.25	2.5	1.5	0.1	10.6
Preirrigated croplands	24.0	0.5	0.25	2.2	0.25	27.7
Evaporation ponds	2.2	0.07	0.25	2.0	2.0	7.2
Miscellaneous	4.5	0.5	0.7	0.7	0.7	7.4

precipitously during the 1980's, except for the Tulare Basin, the proportional species composition of Central Valley waterfowl in relation to Pacific Flyway populations changed little (U. S. Fish and Wildlife Service 1987). However, aerial surveys conducted during January from 1973 to 1977 (U. S. Fish and Wildlife Service 1978) indicated that in the Tulare Basin, pintail previously represented a much greater proportion of the total ducks (Table 2).

The amount of preirrigation observed during aerial waterfowl surveys declined between the late 1970's and the 1980's (Table 3). The largest decline was for August and September, a period that traditionally has the greatest influx of migrating pintail and high use of preirrigated grain fields. Furthermore, evaporation pond habitat consisted of <230 ha during the 1970's but has expanded to nearly 3,000 ha in the 1980's. Thus, the period 1973-1977 preceded the shift in cropping patterns towards more salt tolerant crops, the development of most evaporation ponds, and the declining use of shallow-flooded preirrigation. We therefore suspect that the declining proportion of pintail between the 1970's and the 1980's in the Tulare Basin may reflect the diminishing availability of preirrigated grains and the increasing availability of evaporation ponds.

Table 2. Species composition patterns for Tulare Basin waterfowl surveys expressed as a mean per cent of total ducks surveyed.

Species	1973-77[a]	1980-87[b]
Northern pintail	74	59
Mallard	3	3
All teal	11	13
Northern shoveler	10	16
Ruddy duck	<1	<6
Other ducks	1	3

[a]U. S. Fish and Wildlife Service, 1978, mid-winter waterfowl surveys conducted in January each year.
[b]This study, all surveys.

Table 3. Preirrigated croplands observed (ha) during aerial waterfowl surveys in the Tulare Basin, California in the 1970's and 1980's.

	1976-1980[a]			1981-1987[b]			
	n	$\bar{x}$ (ha)	SE	n	$\bar{x}$ (ha)	SE	Change
August-September	6	2,616	243	5	1,062	278	-60%
October-December	9	1,630	290	29	1,141	168	-30%
January-March	6	1,097	395	21	620	145	-43%
Total	21	1,760	216	55	937	113	-47%

[a] U. S. Fish and Wildlife Service, 1985.
[b] This study.

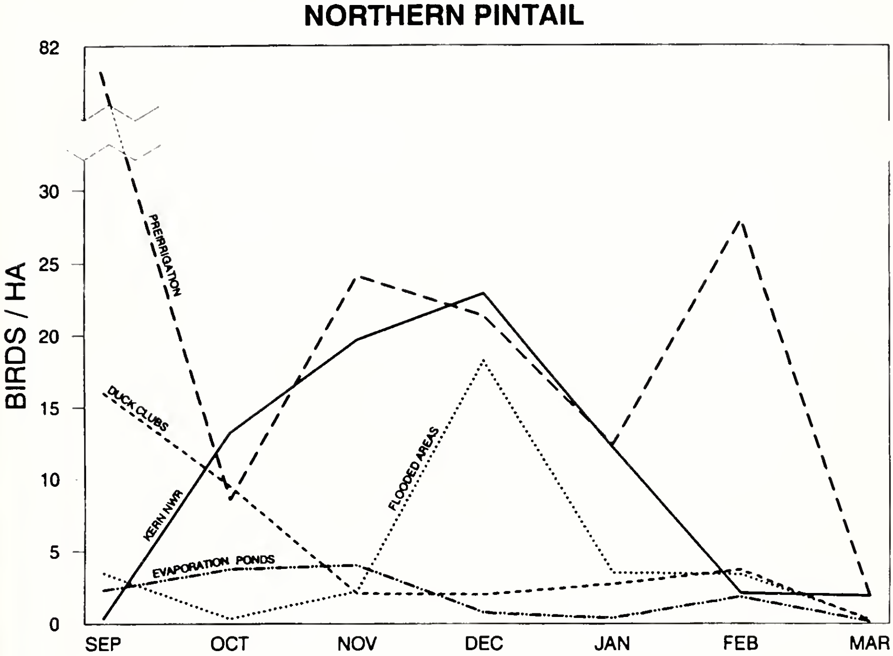
Mallard

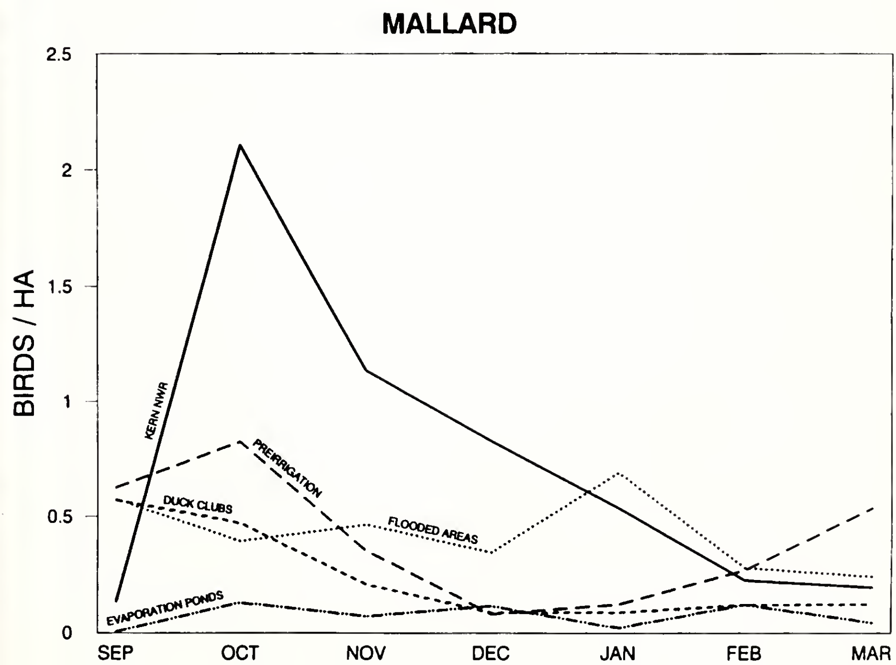
The overall GLM was significant ($F = 2.11$, $df = 90, 162$, $P = 0.0001$) and explained about 50% of the variation in mallard densities ($R^2 = 0.539$). However, this variability was primarily associated with yearly changes in mallard densities because we detected no significant effect due to month, habitat or their interaction ($P > 0.085$). Although not statistically significant, overall mallard density was greatest on Kern NWR (Table 1), particularly for October through December (Fig. 1), and nearly 40% of all mallard were observed there. Mallard accounted for <3% of all ducks observed and <3% of the ducks counted on Kern NWR. However, the proportion of mallard in the wintering duck population of the Tulare Basin remained constant from the 1970's to the 1980's (Table 2).

Northern Shoveler

The GLM for shoveler was significant ($F = 2.53$, $df = 90, 162$, $P = 0.0001$) and accounted for over half of the variation in shoveler densities ($R^2 = 0.584$). Although densities did not differ significantly among habitats ($P = 0.106$) or among months ($P = 0.697$), there was a significant month x habitat interaction ($P = 0.003$). From September through November densities were highest on preirrigated fields, but from December through March they were highest on Kern NWR. Although shoveler appeared to utilize most if not all wetland habitats in the Tulare Basin, because of elevated densities from December through March, Kern NWR had the highest overall density of shoveler (Table 1). Kern NWR held the most shoveler (35% of total shoveler seen) followed by evaporation ponds (25%), preirrigated croplands (15%) and hunting clubs (15%). Shoveler represented about 16% of the total ducks counted in the Tulare Basin. The proportion of shoveler in the total duck population increased slightly from the 1970's to the 1980's (Table 2) possibly due to the rapid increase in invertebrate-rich evaporation ponds (Euliss 1989).

Figure 1. Average monthly density (birds/ha) of waterfowl on five wetland habitats in the Tulare Basin, California, September to March 1980-87.





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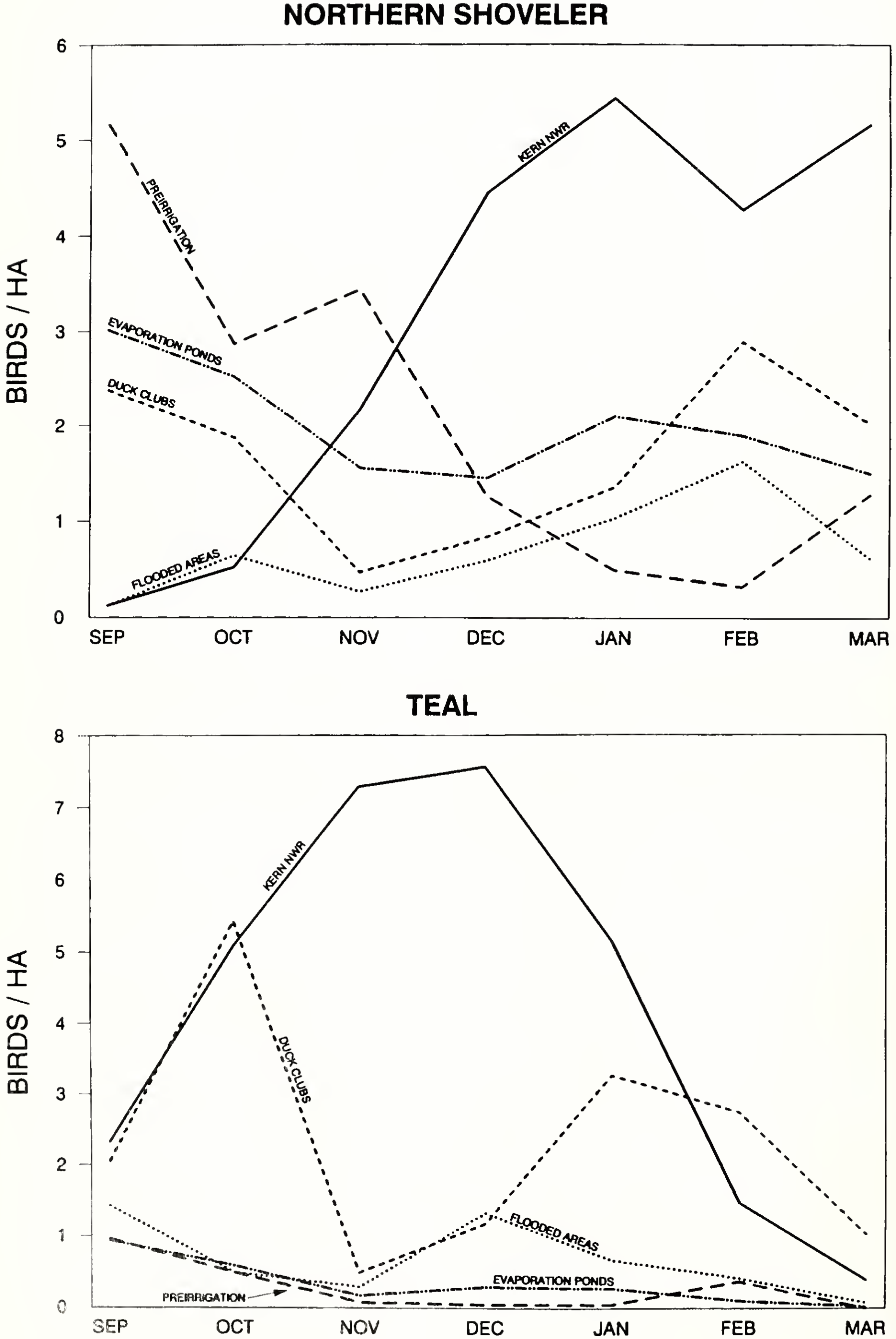

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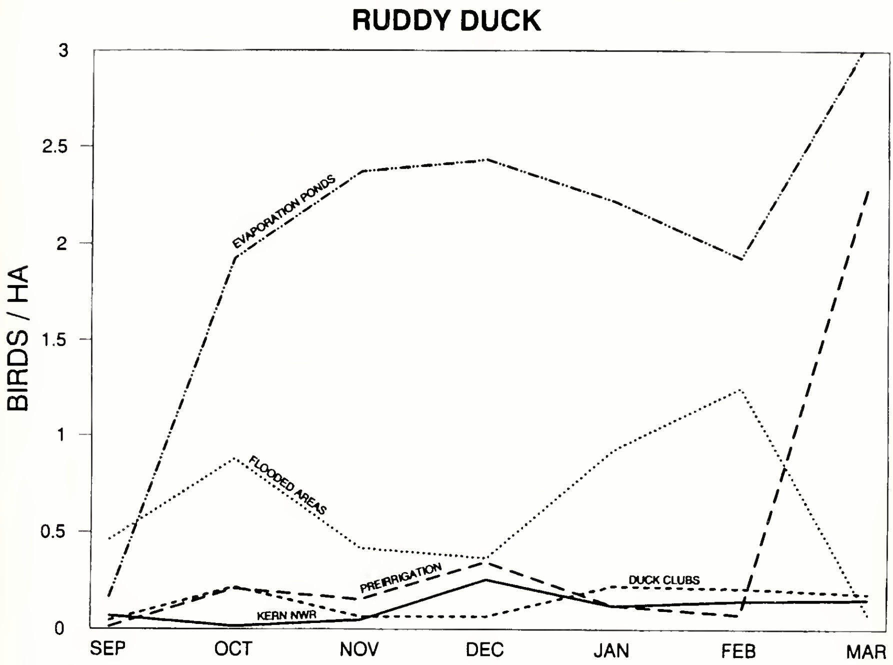

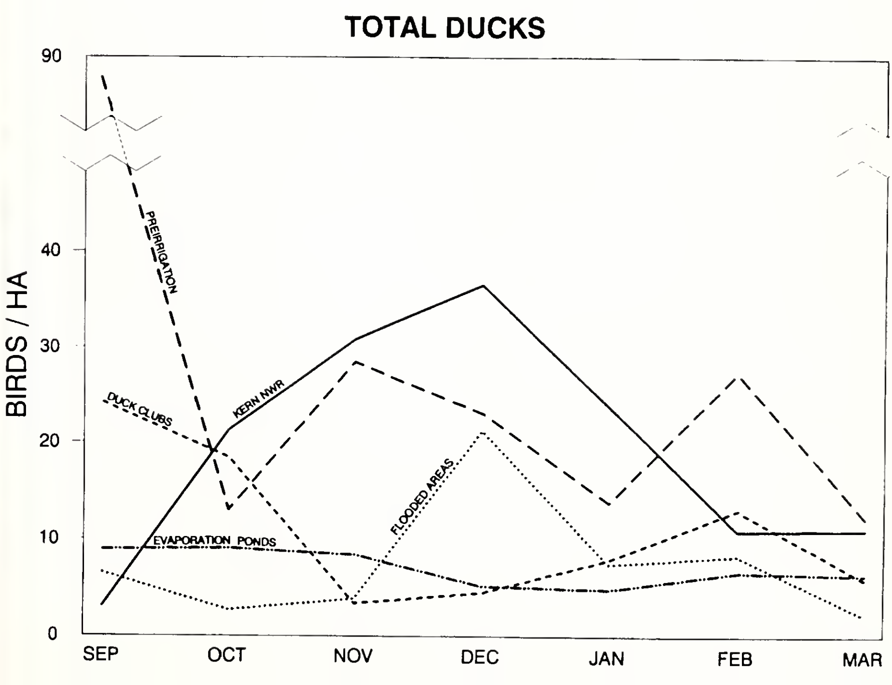

Teal

The overall GLM for teal was significant ($F = 2.75$, $df = 90, 162$, $P = 0.0001$) and explained over half of the variation in teal densities ($R^2 = 0.604$). We detected significant differences among habitats ($P = 0.002$). When averaged over all months, Kern NWR had the highest teal density (Table 1), but a significant month x habitat interaction ($P = 0.008$) indicated that teal densities among habitats was not consistent during all months. In fact we observed high densities of teal on Kern NWR from October through January whereas we observed high densities on hunting clubs during October and from January through March. Combining counts of green-winged and cinnamon teal during the censuses may have affected our results. The effect of month was not significant ($P = 0.248$) but our observations from ground surveys suggest that green-winged teal were most abundant from September through February whereas cinnamon teal abundance peaked from February through June. Teal represented 13% of the total ducks counted during the survey period. Kern NWR and hunting clubs contained 90% of the teal observed. The proportion of teal in the total duck population has remained similar for the 1970's and 1980's (Table 2).

Ruddy Duck

The GLM for ruddy duck was significant ($F = 4.38$, $df = 90, 162$, $P = 0.0001$) and explained much of the variation in ruddy duck densities ($R^2 = 0.708$). Habitat was the most important variable affecting density and distribution of ruddy duck in the Tulare Basin. Over 75% of all ruddy duck were observed on evaporation ponds where, over all months, they occurred at significantly higher densities ($P < 0.001$) than on any other wetland habitat (Table 1). Overall densities in miscellaneous wetlands were also higher than in remaining wetlands (Table 1). However, a significant month x habitat interaction ($P = 0.039$) again indicated that densities within habitats were not consistent among months (Fig. 1). This inconsistency was represented by low densities during September and March on evaporation ponds and miscellaneous wetlands respectively, whereas high densities were observed during March on preirrigated fields. Ruddy duck accounted for about 6% of total ducks, an increase over proportions observed in the 1970's (Table 2). The greater water depth of evaporation ponds may make them more attractive for diving ducks than other wetlands in the Tulare Basin. Moreover, these wetlands produce large standing crops of invertebrates known to be eaten by ruddy duck (Euliss 1989).

Total Ducks

The overall GLM for total ducks was significant ($F = 3.43$, $df = 90, 162$, $P = 0.0001$) and explained over 50% of the variation in waterfowl densities ($R^2 = 0.656$). Over all months we detected significant differences among habitats ($P = 0.002$). Kern NWR and preirrigated croplands had higher densities of total ducks than remaining wetlands (Table 1). These 2 wetland classes accounted for about 26% and 28% of all ducks

observed respectively even though each provided <8% of total wetland area. About 11% of total ducks were observed on hunting clubs, and 9% on evaporation ponds. Although 26% of all ducks were observed on miscellaneous wetlands these wetlands provided an average of about 70% of total wetland area. Miscellaneous wetlands provided little other than open water areas for diurnal resting since the largest area in this class included >35,000 ha of deep- flooded (>2 m) cotton fields. The frequency of water on the floodwater storage basins (averaging 1 of every 3 years; Tulare Lake Basin Water Storage District 1981) that make up about 20% of miscellaneous wetlands and capable of producing some duck foods precludes the development of suitable habitat (T. J. Charmley, pers. comm.).

A significant month x habitat interaction ($P < 0.001$) indicated that densities of total ducks within habitats were not consistent during all months (Fig. 1). Densities were greatest in September on preirrigated croplands ($\bar{x} = 88.2$ ducks/ha) and hunting clubs ($\bar{x} = 24.2$ ducks/ha). An influx of pintail was largely responsible for higher densities of total ducks in September. Densities were similar among months in evaporation ponds and the miscellaneous wetlands. Despite high densities on preirrigated croplands and hunting clubs in September, densities declined and were similar among other months. Kern NWR had low densities in September and in February and March, but had high densities from October through January. We believe this density pattern occurred because Kern NWR did not receive water allocations until mid- October and managed units were not flooded until early November. Kern NWR provided a mixture of deep and shallow freshwater marshes managed for moist-soil plants in seasonally flooded wetlands. We suspect the diversity of habitat on Kern NWR enabled it to meet critical nutritional, bioenergetic, and resting requirements of many wintering ducks. Further, 40% of Kern NWR was managed as sanctuary (Euliss 1984) and thus may have affected duck use due to high hunting pressure on most of the surrounding wetlands.

CONCLUSIONS

It is important to be reminded that this analysis pertains to diurnal duck densities only. Nocturnal habitat use by ducks may be very different than diurnal use and would therefore yield different densities. We observed low densities for most species on evaporation ponds, hunting clubs and miscellaneous wetlands. Most hunting clubs were small, isolated parcels of wetland (Jones and Stokes 1988) with food production limited by cost and availability of irrigation water (R. O. Hulbert pers. comm.). The low densities we observed on these wetlands suggest that they were not heavily used by wintering ducks. However, hunting clubs provided habitat important for attracting ducks away from contaminated evaporation ponds in September and again in late winter (January-February). Evaporation ponds were not heavily used by ducks. but the large area provided by evaporation ponds may affect use of these habitats in the future.

Density for all species, except ruddy duck, was highest on preirrigated croplands or Kern NWR (Table 1). Ducks such as mallard and teal that use densely vegetated wetlands were probably attracted to the diversity of vegetative cover on Kern NWR.

Other species such as pintail make use of Kern NWR's managed areas for diurnal feeding and resting. Preirrigated croplands had the highest density of pintail. The value of these shallow-flooded wetlands with their available waste grains may be similar to that of rice fields in the Sacramento Valley (Miller 1989). Moreover, preirrigated fields provided large expanses of open water for diurnal resting locations important to pintail for predator detection (Tamisier 1976).

Although farmers will continue preirrigating agricultural fields in the Tulare Basin and elsewhere in the San Joaquin Valley, changing methods of preirrigation and installation of subsurface drains will decrease the area of preirrigated cropland for waterfowl habitat while the area provided by evaporation ponds will increase. Ultimately habitat for wintering ducks, especially pintail will be lost. Unless shallow freshwater habitat is provided to replace the loss of preirrigated croplands and to offset expanding evaporation pond habitat, we expect that fewer ducks will winter in the Tulare Basin.

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ATTACHMENT METHOD FOR RADIO TRANSMITTERS ON MALLARD DUCKLINGS

DENNIS L. ORTHMEYER[1]
U. S. Fish and Wildlife Service
Montana Cooperative Wildlife Research Unit
University of Montana
Missoula, MT 59812

Two methods of attaching, glue and suture-glue, 1.8-g radio transmitters to mallard *(Anas platyrhynchos)* ducklings were evaluated. Neither method affected weight gain. Radio transmitters attached with glue detached from 4 of 6 ducklings during pen tests, whereas only 1 of 6 of the transmitters attached by the suture-glue method became detached. A field test indicated that radio transmitters attached by the suture-glue method were able to withstand natural conditions without detaching.

INTRODUCTION

Radio transmitters and attachment methods have been developed for passerine birds (Fitzner and Fitzner 1977, Martin and Bider 1978, Raim 1978, Rothstein et al. 1984, Sykes et al. 1990), but until recently, externally-mounted transmitters that were small enough to use on newly-hatched ducklings were not available. Duckling survival rate must be determined to assess waterfowl recruitment (Cowardin et al. 1985), and this requires marking individual ducklings to determine specific causes of mortality (Orthmeyer 1987). Despite the recent availability of transmitters suitable for ducklings, methods that facilitate attachment of transmitters to ducklings for the life of the transmitters were lacking.

This paper describes pen and field evaluations of 2 methods of attaching radio transmitters. The harness attachment method (Perry et al. 1981) was not effective on the common yellowthroat (*Geothlypis trichas*) and was not tested in this experiment, due to the growth rates of the ducklings.

METHODS

Transmitter Construction

The radio transmitter was constructed of an SM-1 transmitter, Hg 365 silver-oxide battery, and 60-mm antenna (components supplied by AVM Electronics Inc., Livermore, CA.). The battery was soldered horizontally to the end of the SM-1 transmitter and to the transmitter lead. The transmitter and battery were then coated with acrylic to make the unit waterproof, leaving one battery and transmitter lead

[1]Present address: United States Fish and Wildlife Service, Northern Prairie Wildlife Research Center, 6924 Tremont Road, Dixon, CA 95620.

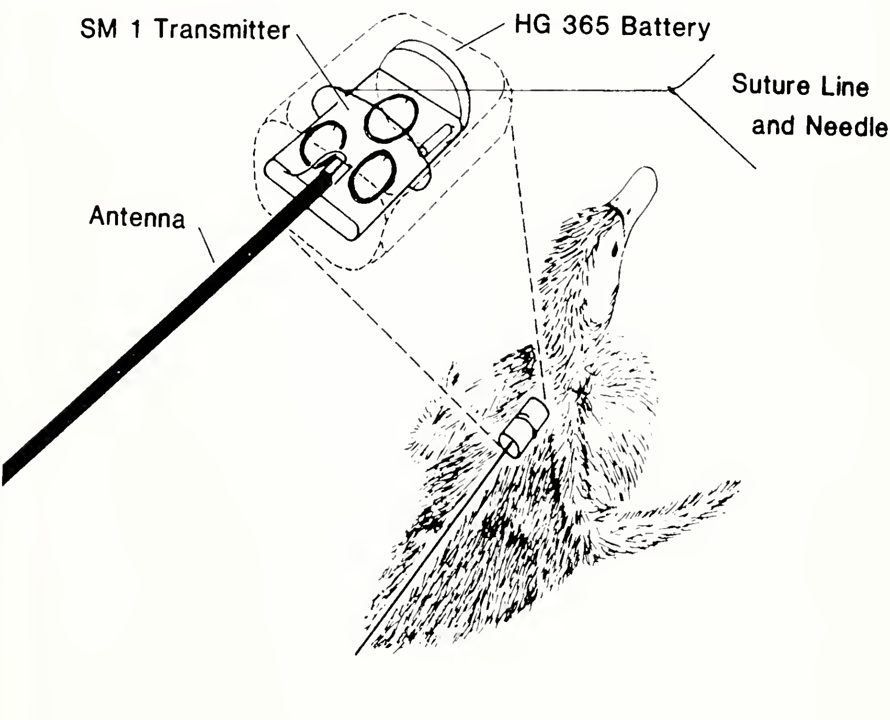
exposed. A loop of suture (unwaxed dental floss) was placed around the radio and secured under an additional coat of acrylic. The exposed leads were connected and covered with acrylic the day the radio was used. The 18 x 10 x 10-mm transmitter weighed 1.8 g, transmitted for 10 days, and transmitted ≤150 m distance.

Attachment

Transmitters were attached to the skin and feathers between the wings (Fig. 1). The glue-only method was identical to the suture-glue method described below except no sutures were used. Using the suture-glue method the duckling's back, the suture, and needle were sterilized with alcohol. The needle was inserted subcutaneously for 0.5 cm on each side of the backbone, and the suture drawn tight under the skin. A permanent-bonding glue (Krazy Glue, Inc., Itasca, Ill.) was applied to the ventral side of the radio, which was placed on the back of the duckling between the wings. The suture was drawn over and glued to the top of the radio while being held tightly. The duckling was held for approximately 1 min before being released.

Pen Test

Figure 1. Radio transmitter design and placement area on mallard ducklings.



The pen study was conducted at the University of Montana Zoology Animal Laboratory from 19 March to 19 April, 1986. Eighteen 1-day-old game-farm mallard ducklings were used in the study. Radio transmitters were attached to 12 ducklings and 6 ducklings served as controls. Radios were attached with glue to 6 ducklings and with the suture-glue method to 6 ducklings. Ducklings were held in a 268 x 85 x 59-cm flooded pen provided with elevated roost sites, heat lamps, and fed ad libitum. Ducklings were weighed daily to the nearest 0.1 g.

Field Test

The field test was conducted using the more successful of the two methods, at Benton Lake National Wildlife Refuge, Great Falls, MT, in conjunction with an ongoing brood-survival study in 1986.

Radios were suture-glued on 2 freshly hatched dry mallard ducklings from two separate nests. Ducklings were returned to their broods, covered with nest down, and quieted by placing my hand over the down-covered brood for 1-2 minutes. All ducklings remained in the nest when I left the nest site.

RESULTS AND DISCUSSION

Pen Test

The mean weight of day old ducklings was 34.3±4.2 g and mean weight gain was 0.13 g/day over a 30 day period. Weight gain of ducklings of both attachment methods and the control group were similar (repeated measures ANOVA, $F = 0.01$, $P = 0.99$, df 2,14).

Four of 6 transmitters attached with glue detached during the pen test; 3 during the first 10 days and the other on day 14. Only one of the transmitters attached by the suture-glue method became loose but the unit did not totally detach during the pen test.

The glue-only method failed 4 times whereas the suture-glue method failed only once; therefore the suture-glue method was the one that was field tested. Sykes et al. (1990) used glue-only to attach transmitters to the common yellowthroats. They found the glue attachment method to be satisfactory in a pen test but the transmitters had a reduced retention time on Kirtland warblers *(Dendroica kirtlandii)* during a field test. I determined that the glue-only method was not appropriate for field testing due to the high rate of attachment failure.

Field Test

The adult female from one nest also was captured and radio-marked in a concurrent investigation (Orthmeyer 1987) at the same time as her duckling. After release, the adult female returned to the nest in <1 hour and immediately moved 2 (including the radioed duckling) of 7 ducklings to the water; 5 ducklings were found dead in the nest bowl the next day. The radio-marked duckling was monitored throughout the

transmitter's life (10 days). Subsequent visual and radio locations of the adult female confirmed both ducklings fledged (Orthmeyer 1987).

The adult female from the second nest had been captured and radio-marked 6 days before the ducklings hatched. This adult female returned to the nest 30 minutes after the duckling was radio-marked and moved with her entire brood to water in <2 hr. The duckling's radio functioned until the radioed duckling and other brood mates moved to water. The transmitter remained attached but ceased to transmit due to electrical or mechanical problems. The duckling, with the radio attached, was sighted with the adult female and brood the next day (Orthmeyer 1987).

CONCLUSION

The glue-only method of radio attachment was found unsatisfactory in a pen test, while a non-knot suture-glue method of attachment was found to be satisfactory in a pen test and field test.

Radio transmitters on ducklings provided information on duckling behavior and movements while the adult female was present and absent. Additional investigations relying on duckling radios may provide data on duckling survival and predators for interpreting the mallard recruitment equation. I recommend that adult females also be radio-marked in addition to ducklings in the brood due to the limited signal range of the duckling radios. High predation rates of young ducklings (Orthmeyer 1987) make it necessary that radio locations of ducklings be recorded at least every 3 hrs. A high probability of abandonment may exist when radio attachment to the adult female occurs at critical time of nest hatch; therefore I suggest radios be attached to adult females from 18-24 days incubation. Nest abandonment did not occur by adult females radioed at 18-24 days into incubation (Orthmeyer 1987).

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EFFECT OF TRIPLOID GRASS CARP ON SUBMERSED AQUATIC PLANTS IN NORTHERN CALIFORNIA PONDS

ROBERT T. PINE and LARS W. J. ANDERSON
USDA Aquatic Weed Control Research Laboratory
Davis, California 95616

Two ponds in Davis, California were divided and stocked with the equivalent of 30 or 60 triploid grass carp, *Ctenopharygodon idella* Val. per hectare to determine effects on Eurasian watermilfoil, *Myriophyllum spicatum* L., sago pondweed, *Potamogeton pectinatus* L., and *Chara* sp. In the east pond, after 15 months, Eurasian watermilfoil had not been affected in the 30 fish/ha section and had been stimulated to grow in the 60 fish/ha section. Sago pondweed was reduced by 80% and 100% and *Chara* sp. was reduced by 2% and 72% at 30 and 60 fish/ha, respectively. At initial stocking, little *Chara* sp. was present in the section with 30 fish/ ha. In the west pond, after 15 months, Eurasian watermilfoil had been reduced by 38% and 24% and sago pondweed by 87% and 100% at 30 and 60 fish/ha, respectively. Based on the above values, triploid grass carp preference was: sago pondweed > Chara > Eurasian watermilfoil ($P < 0.05$). A filamentous alga, *Cladophora* sp., disappeared from areas not surrounded by exclosures nine months after fish introduction. Nutritional variables of Kjeldahl nitrogen, fat, ash, and acid detergent fiber did not correlate with plant fresh weight consumed.

INTRODUCTION

Triploid grass carp are currently being assessed for their ability to control submersed aquatic plants in northern California (Pine et al. 1989, 1990*a*). This assessment is becoming more important as a result of increasing interest by various potential users in having this fish introduced into the area (California Department of Fish and Game 1989). Several studies have been conducted in pond settings using diploid and triploid grass carp to assess plant preferences and consumption rates (Avault 1965, Michewicz et al. 1972, Edwards 1974, Fowler and Robson 1978, Haller and Sutton 1978, Kilambi and Robison 1979, Wiley and Gordon 1984, Leslie et al. 1987). Triploid grass carp are a functionally sterile (Van Eenennaam 1990) strain of grass carp that have proved to be effective in controlling aquatic plants in southern California (Stocker and Hagstrom 1986). Studies have been conducted to relate important nutritional variables of aquatic plants to plant preferences and consumption rates by grass carp (Tan 1971, Stanley 1974*a*, 1974*b*, Wiley and Wike 1986). Stroganov (1963) found that water temperature was the most important factor influencing preference and consumption rate. He found that diploid grass carp cease to eat at water temperatures below 13°C. At temperatures over 16°C, feeding becomes more intense and less selective. Jobling (1981) found that consumption rate in some fish was directly correlated with dietary protein levels.

The purpose of this study was to compare two stocking rates of triploid grass carp

in two ponds, one containing a mixed population of Eurasian watermilfoil, sago pondweed, and *Chara* sp., and the other containing predominantly Eurasian watermilfoil with a small amount of sago pondweed. A floating filamentous alga was also present in this pond. A second purpose was to correlate plant protein (Kjeldahl nitrogen), fat, ash, and acid detergent fiber (ADF) with triploid grass carp consumption.

MATERIALS AND METHODS

Two 0.2 ha plastic lined ponds located at the USDA-ARS Aquatic Weed Control Research Laboratory at Davis, California were used in this study. Pond depth ranged from 0.8 to 1.5 m. Silt covering the bottom of these ponds averaged 46 cm deep. In the west pond, Eurasian watermilfoil was present as the dominant submersed species with floating filamentous algae covering about 25% of the surface (Fig. 1). Sago pondweed at less than 1% of total plant mass was interspersed with the Eurasian watermilfoil. Based on a visual estimate of coverage, the east pond had 70% Eurasian watermilfoil, 20% sago pondweed, and 10% Chara as submersed species (Fig. 1). A 2 m wide, plastic coated, 2.5 cm mesh, nylon net was used to divide each pond in half. Metal wire (1.0 cm mesh) was laid over the top half of the nets and extended 0.5 m into the water column to protect from damage caused by mammals and birds. Metal posts set in concrete were placed diagonally across the ponds to support the nets. Eight welded wire exclosures, 1 m in diam, were placed in each pond section to serve as controls.

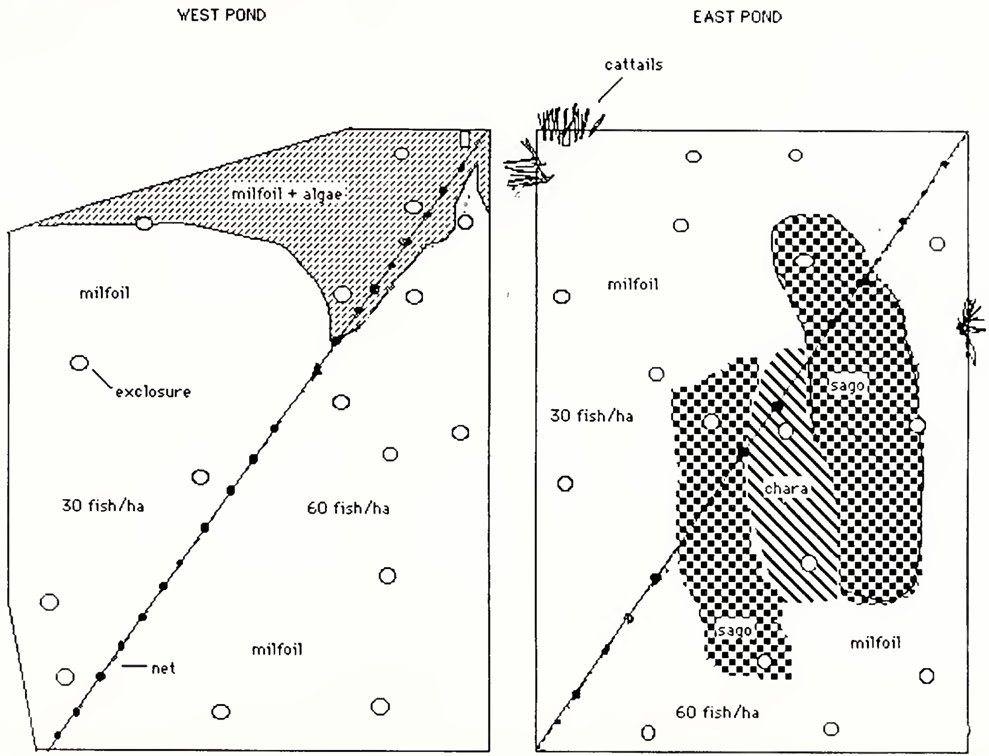
Each of the two ponds was treated in December 1987 with 2 l of 0.5% rotenone to remove existing fish. Triploid grass carp that had been certified through use of flow cytometry (Pine and Anderson 1990*b*) were held in a 10,000 l, fiberglass pool covered with 50% shadecloth for three months prior to stocking. The pool was supplied with aerated water that had passed through a gas stripper at a flow rate to provide a 24 h turnover. Temperatures in the pool varied between 9 and 250° C. Fish were fed ad libitum with an equal (by weight) mix of the three species of submersed plants in the ponds plus lettuce, *Lactuca sativa L.* and Purina Catfish Chow for a month prior to the experiment.

A 180 day, 5-35°C recording thermograph (Peabody-Ryan Instruments)[1] was placed on the bottom of both ponds immediately prior to fish introduction. The following water quality data were determined at 1200 hours on a monthly basis, before and during the experiments: total alkalinity, total hardness, conductivity, pH, dissolved oxygen, and turbidity. A Hach kit was used to measure total alkalinity and total hardness, a Hydrolab System 8000 was used to measure conductivity, pH, and dissolved oxygen, and an HF Instruments Model DRT 15 was used for turbidity measurements.

At the start of the experiment, 18 triploid grass carp were anesthesized with quinaldine sulfate at 10 mg/l for 15-30 min. Fish total length (tl), fork length (fl), and wet wt were then measured. Either 3 or 6 fish were added to pond sections on 10 August

[1]Mention of a manufacturer does not constitute a warranty or guarantee of the product by the US Department of Agriculture nor an endorsement by the Department over other products mentioned.

Figure 1. Area covered by aquatic plants in west and east ponds at the USDA Aquatic Weed Research Laboratory in Davis, California. Diagonal lines indicate nets dividing ponds. Circles indicate exclosures.



1988, giving stocking rates equivalent to 30 or 60 fish/ha. Fish were removed on 7 November 1989 again using 2 l of 0.5% rotenone, which proved lethal to triploid grass carp. No other fish were observed. Measurements were repeated at this time.

Four 1 m diam plant biomass samples were taken randomly from each section of the ponds prior to fish stocking, at the middle of the experiment, and at the end of the experiment. Total plant fresh wt was measured for each sample and used to estimate total amount of plant material consumed as a percent of plants in the unstocked control sections. Initial (pre-stocking) control values were subtracted from final values to determine net plant growth during the experiment (Pine et al. 1989). Consumption was then corrected using this information. Biomass from the exclosures was averaged for each plant species in both ponds during each sample date in calculating the percent of control fresh wt biomass for the two stocking rates. Floating filamentous algae was not measured. Observations were made to document consumption of algae.

Plants were dried and then ground in a Wiley mill. At least 500 g of dried, ground material of each plant species was composited into each sample. Kjeldahl nitrogen (protein), fat, and ash were measured by the AOAC (1984) method. Acid detergent fiber, the undigestible lignocellulose plus ash, was measured (Van Soest and Wine 1967).

Statistical analysis of percent of control fresh weight comparisons were done with arcsine transformed data using ANOVA. Comparisons between proximate analysis and Van Soest analysis variables were done with arcsine transformed data using Duncan's Multiple Range Test. Correlations between proximate and Van Soest analysis variables and percent of control fresh wt comparisons were done with arcsine transformed data using linear regression. Tests were done at $P < 0.05$ significance level.

RESULTS AND DISCUSSION

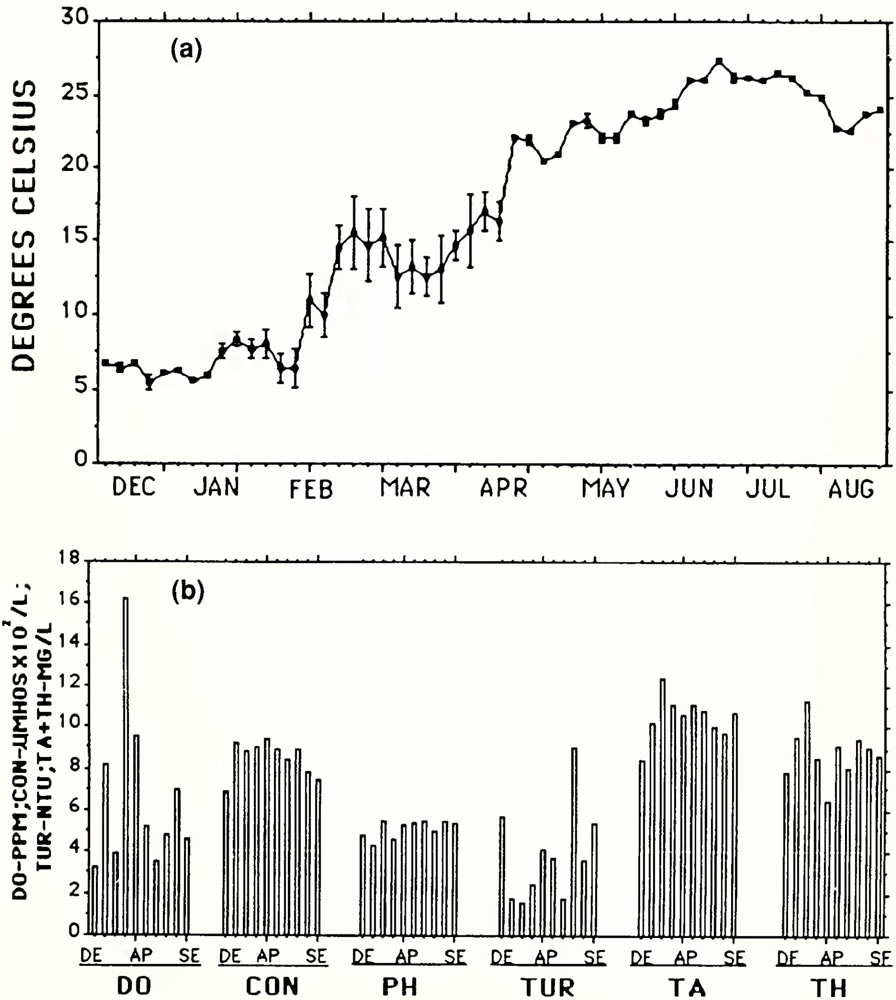
By the end of the experiment, in November, 1989, the fish had increased their fresh wt by 8 fold, and their fork length had nearly doubled from initial values (Table 1). Daily temperature fluctuation was greatest from February to April (Fig. 2). Water quality was very similar for both ponds and could be demonstrated with the values measured in the east pond (Fig. 2). Changes in water quality could be explained by conditions associated with change of season.

Fresh weight percent of control was calculated for Eurasian watermilfoil, sago pondweed and Chara sp. (Fig. 3). No Chara was present in the west pond. At the November sampling date, lack of control of Chara in the 30 fish/ha section in the east pond compared with partial control at the May sampling date indicated that plant growth rate was faster than fish consumption rate during the summer months. At the November sampling date, Eurasian watermilfoil biomass in the 60 fish/ha section in the east pond was greater than control values. This may have been caused by plants "overcompensating" as a result of herbivory (Belsky 1986). In the west pond, where the most preferable plant, sago pondweed, was almost completely eliminated at both stocking rates, much more of the watermilfoil was consumed (Fig. 3). Based on fresh

Table 1. Initial and final total length (TL), fork length (FL), and wet wt. ± SD for triploid grass carp stocked in two California ponds.

	30 fish/ha			60 fish/ha		
	TL(mm)	FL (mm)	Wet wt. (g)	TL(mm)	FL (mm)	Wet wt. (g)
Initial	235±10	219±22	140±19	247±20	222±20	163±38
Final	426±56	398±30	1,065±79	431±13	404±14	1,051±59

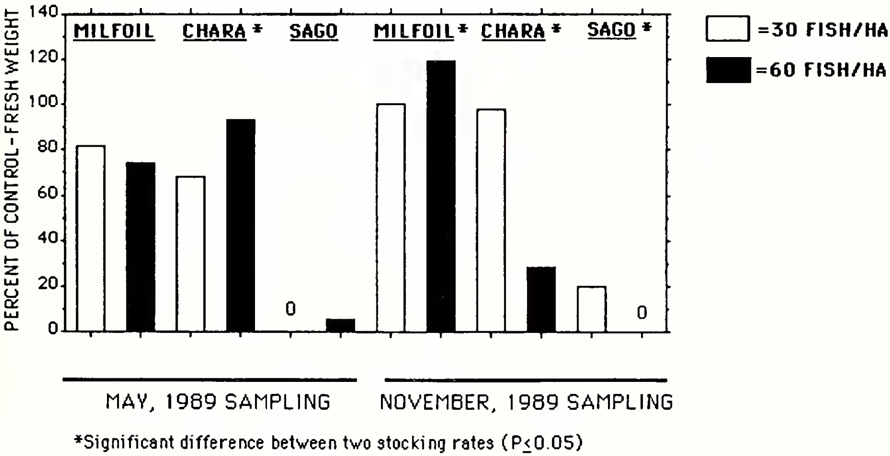
Figure 2. (a) Mean daily temperature of east pond from January, 1989 to December, 1989. Error bars show the range of six values taken at 0200, 0600, 1000, 1400, 1800, and 2200 hours. (b) East pond water quality values for dissolved oxygen (DO), conductivity (CON), pH, turbidity (TUR), total alkalinity (TA), and total hardness (TH) from December (DE), 1988 to September (SE), 1989. Readings were taken at 1200 hours on the 15th of each month.

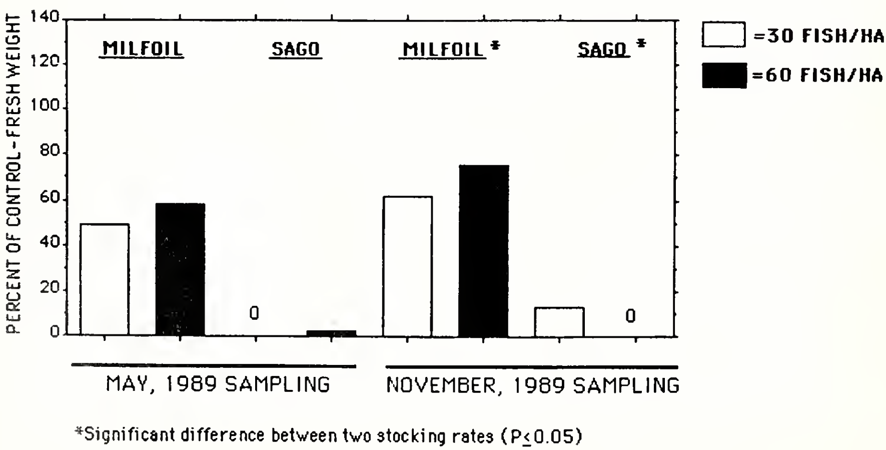


weight percent of control in the two ponds, fish preference was sago pondweed > Chara > Eurasian watermilfoil ($P < 0.05$). Floating filamentous alga was observed to have disappeared from all areas of the west pond except within the exclosures by the May, 1989 sampling.

Proximate and Van Soest analysis showed no significant differences ($P < 0.05$) in nutritional content within plant species between ponds (Fig. 4). Significant differences occurred between plant species ($P < 0.05$). Chara was significantly different from Eurasian watermilfoil and sago pondweed in respect to Kjeldahl nitrogen, fat, acid detergent fiber (ADF), and ash in the east pond. Eurasian watermilfoil was significantly

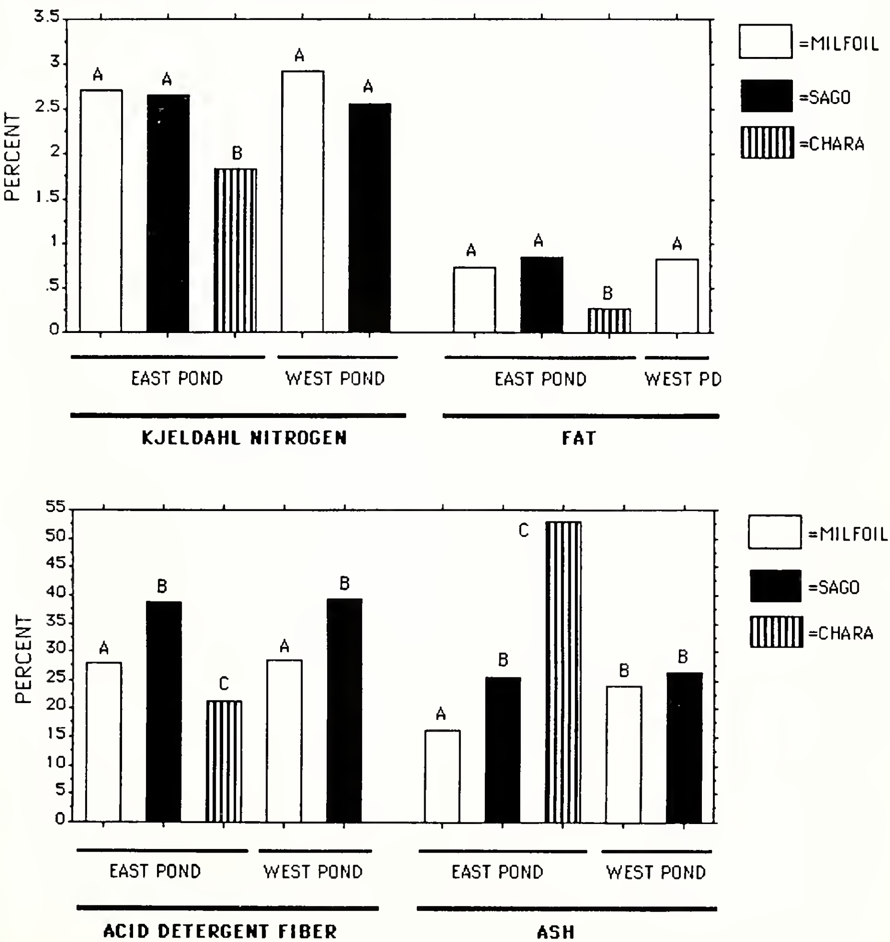
Figure 3. Comparison of triploid grass carp preference and consumption rate of three plant species at two stocking rates in the east pond (top) and west pond (bottom). Chara was not present in the west pond. The variable of comparison is the mean plant fresh weight from areas stocked with fish as a percent of mean plant fresh weight from exclosures. Each bar represents the mean of 4 values. An asterisk next to a plant label represents significant differences within-species comparisons of stocking rates based on ANOVA of arcsine transformed data.





lower ($P < 0.05$) than sago pondweed in the east and west ponds in respect to ADF. Ash content in the east pond with Eurasian watermilfoil was significantly lower ($P < 0.05$) than sago pondweed and Chara. No significant correlations ($P < 0.05$) were found between any of the proximate or Van Soest analyses run and fresh weight percent of control values. Optimal foraging theory (Townsend and Winfield 1985) is used to explain preference, since preference was not determined by plant nutritional elements. The most important factor determining preference in triploid grass carp is handling time (Pine et al. 1989). Handling time (as determined by accessibility of plants to the fish and ease with which fish chew the plant material) would make plants

Figure 4. Comparison of proximate analysis and Van Soest analysis variables of Kjeldahl nitrogen, fat, acid detergent fiber, and ash in the east and west pond using plant samples taken before stocking with fish. Each bar represents the mean of 4 values. Letters above bars represent within-analysis comparisons based on Duncan's multiple-range test of arcsine-transformed data. Bars with similar letters within an analysis are not significantly different ($P > 0.05$) from each other.



lacking in branching, such as sago pondweed, and soft, easily chewed plants, such as filamentous algae or hydrilla, *Hydrilla verticillata* Royle, more preferable.

Our data indicate that elimination of surface biomass of less preferred plants, such as Eurasian watermilfoil, in ponds in a 15 month interval was not achieved with the stocking rates used in this study. Higher stocking rates, larger fish or longer time intervals might be needed to eliminate these plants. Alternatively, one might partially drain ponds in summer or winter so that exposed plants dryed or froze, respectively, or mechanically harvest plants to reduce initial biomass before stocking. A contact-type herbicide might also accomplish plant biomass reduction that might allow a faster elimination of plants by triploid grass carp. In situations where environmental disturbance should be minimized, such as waterfowl habitats or larval fish refuges, a longer time interval to achieve plant elimination might be desired. Organisms would have a chance to adapt to the changed environment. In these situations, partial elimination of plants might also be acceptable or desired.

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FOOD CONSUMPTION RATE OF JUVENILE DWARF SURFPERCH, *MICROMETRUS MINIMUS*: TEMPERATURE AND TEMPORAL EFFECTS

Garwin M. Yip and Joseph J. Cech, Jr.
Department of Wildlife and Fisheries Biology
University of California, Davis
Davis, California 95616

Food (adult brine shrimp, *Artemia*) consumption rates of juvenile dwarf surfperch (*Micrometrus minimus*) were measured at three temperatures. Surfperch consumed significantly more food ($P < 0.05$) at 19°C and at 23°C than at 13°C. Surfperch at warmer temperatures showed significantly higher consumption at early (0900) and late (2100) feedings than at intermediate daylight hours (1300, 1700).

INTRODUCTION

Dwarf surfperch (*Micrometrus minimus*, Embiotocidae) are restricted to shallow, inshore marine and estuarine environments (Terry and Stevens 1976). Because these environments often experience wide diurnal or seasonal temperature changes and because temperature has such a profound effect on metabolic and related rates (see review by Brett and Groves 1979), we measured effects of temperature on food consumption rates of juvenile dwarf surfperch.

METHODS

The 135 young-of-the-year dwarf surfperch needed for the study were either seined from Tomales Bay (Marin and Sonoma Counties, CA) beaches, at water temperatures spanning 14.5°C to 21°C, or were born in the laboratory from pregnant females caught at the same sites. Fish were quickly transported 32 km to the University of California Bodega Marine Laboratory in oxygenated, insulated coolers. The laboratory was maintained on a ca. 15L:9D photoperiod, simulating the natural photoperiod. After 1 week acclimation at 15°C-16°C in a 300-l fiberglass tank with a continuous seawater inflow, fish were weighed (Mettler electronic balance) and randomly distributed among 9, 40-l plexiglass aquaria. Each aquarium was provided with aeration, a plastic aquarium plant for cover, and a constant flow of filtered seawater (34 ppt salinity). Fish were starved for 24 h prior to the initial and final weighings to minimize effects of retained food. Fish were gradually temperature-adjusted (submersible aquarium heaters) to experimental temperatures (13°, 19°, and 23°C) over a 3 d period. Then, the 3 replicate aquaria were maintained at the experimental temperatures (checked twice- daily) over the 15 d experiment.

Fish were fed measured quantities of live, adult brine shrimp (*Artemia* sp.) ad. lib. every 4 h at 0900, 1300, 1700, and 2100 h. A brine shrimp subsample was weighed and

counted from each commercially obtained batch to determine the mean (± SD) wet weight of each brine shrimp (6.3±1.3mg). Uneaten food was then netted out, along with any visible feces. Uneaten brine shrimp were counted, and their weight subtracted from the total food fed to the aquarium of fish to determine amount of food consumed. Food consumption per fish was calculated, excluding fish which were alive, but did not eat. On experiment day 2, the heater in a 23°C aquarium malfunctioned, killing all of the fish. Because these fish were fed only 1 d, data from that aquarium were not included in the final calculations. Besides this accident, fish mortality was minimal (<15%).

Food consumption and temperature data were analyzed (P <0.05) via ANOVA. Instantaneous (=specific) growth rates (G) for each aquarium, expressed as % wet body weight/day, were calculated from:

$$G = 100\,(\log_e W_2 - \log_e W_1) \cdot t^{-1}$$

where: W_1 = mean initial estimated wet weight (g);
W_2 = mean final wet weight (g);
t = duration of experiment (days).

Gross conversion efficiencies (GE) were calculated as:

$$GE = 100\,(W_2 - W_1)(F \cdot t)^{-1}$$

where: F = mean wet weight of food (g) consumed/fish daily; (Wurtsbaugh and Cech 1983). Kruskal-Wallis analyses compared calculated specific growth rates and gross conversion efficiencies among temperature groups. A repeated-measures ANOVA compared food consumption rates of each temperature group among the four feeding times to elucidate temporal consumption patterns.

RESULTS

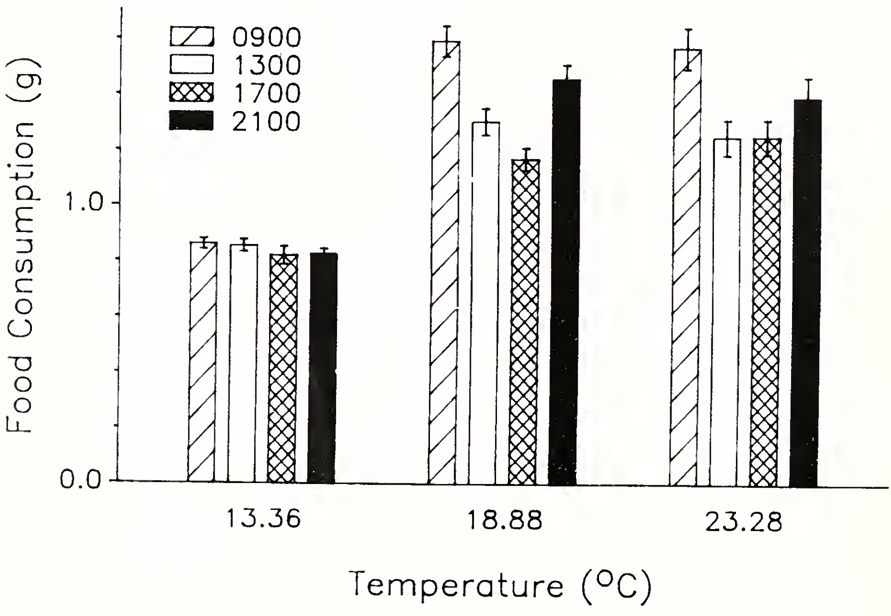
Water temperatures of replicated aquaria within a temperature group were not significantly different whereas temperatures between groups were significantly different (Table 1). Food consumption rate at 13°C was significantly lower than that at 19°C or 23°C, but rates at 19° and 23°C were not significantly different (Table 1). Fish initial body weights and final body weights were not significantly different, either within or between groups (Table 1). Thus, no temperature-related effects on growth were detected, possibly due to the brevity of the study. Similarly, specific growth rates and conversion efficiencies were not significantly different among temperatures. However, specific growth rates indicated a trend towards faster growth at 19°C and 23°C compared with 13°C, whereas conversion efficiencies showed a higher trend at the cooler temperatures (Table 1). Fish at 13°C showed no temporal differences in food consumption rate (Fig. 1). In contrast, fish at both of the warmer temperatures showed a significantly increased rate at 0900 h compared with the 1300 and 1700 rates,

Table 1. Dwarf perch food consumption and conversion efficiency[1].

Variable	Temperature (°C) 13.36[a]±1.18	18.88[b]±0.52	23.28[c]±0.88
Food consumption rate (g food/fish/feeding)	0.0667[d]±0.0091	0.0974[e]±0.0177	0.0962[e]±0.0207
Initial Fish weight (g)	0.927[f]±0.376	0.959[f]±0.357	0.905[f]±0.282
Final fish weight (g)	1.234[f]±0.570	1.350[f]±0.601	1.237[f]±0.502
Specific growth rate (%wet body weight/day)	1.893±0.214	2.237±0.637	2.235±0.290
Conversion efficiency (growth/food consumption)	7.577±0.835	6.547±1.835	6.205±0.318

[1]Data are grand means ±SD computed from replicate means. Data in the same row with different superscripts are significantly different ($P < 0.05$, ANOVA).

Figure 1. Temporal effects of temperature on food consumption rates (mean ± SE) of juvenile dwarf surfperch.



and the 19°C fish also showed an increased 2100 rate compared to the 1300 and 1700 rates.

DISCUSSION

The level pattern of dwarf surfperch food consumption at the higher experimental temperatures (Table 1) may signify close proximity to an upper boundary of metabolic and thermal efficiency. This is also indicated by the leveling of specific growth rates at 18-23°C. The declining trend in conversion efficiency with increasing temperature (Table 1) could also be explained by a food consumption rate which fails to keep pace with an increasing metabolic rate. Elevated temperatures generally increase metabolic rates of fishes (see review by Brett and Groves 1979). An example is provided by juvenile mosquitofish (*Gambusia affinis*), another livebearing fish. Mosquitofish showed increased metabolic rates with increased temperatures through the 10-35°C range (Cech et al. 1985). Mosquitofish food consumption followed a similar pattern except for a levelling off at 30-35°C (Wurtsbaugh and Cech 1983). Resulting slight declines were measured in specific growth rate and conversion efficiency with the 30-35°C increase (Wurtsbaugh and Cech 1983), which is near the incipient lethal level of 37-38°C (Otto 1973).

One metabolic cost concerns activity. Wurtsbaugh and Cech (1983) measured activity increases as temperature increased between 15° and 25°C in mosquitofish. Although not quantified in our experiments, the fish at 13°C waited at the bottom of the aquaria for their food while at 19°C and 23°C, the fish vigorously swam up to the top of the aquaria when fed.

Temperature also played a role in this species' temporal food consumption patterns (Fig. 1). Our fish at 13°C showed no difference in consumption rate through the day, possibly indicating that their guts were not emptying completely through the 12-hour night period. Freshwater roach (*Rutilus rutilus*) and marine pipefish (*Sygnathus fuscus*) both showed slower gut transit times in colder water (Hofer et al. 1982, Ryer and Boehlert 1983). The higher mean consumption rates at 0900 (compared with the 1300 and 1700 feedings) may indicate more complete overnight gut emptying at the two warmer temperatures and an enhanced early morning hunger state. Alternatively, the higher mean 2100 rates (compared with 1300 and 1700, significant at 19°C) may indicate a crepuscular feeding rhythm in this species, a trait noted in other planktivorous fishes (see review by Townsend and Winfield 1985).

Juvenile dwarf surfperch may select cooler to medium water temperatures for bioenergetic reasons. Although our fish at 13°C had a comparatively lower food consumption rate, their mean gross conversion efficiency of 7.58% results in high bioenergetic efficiency. At 19°C, the fish had the highest mean food consumption rate, although their mean conversion efficiency of 6.55% was lower than that shown by fish at 13°C. Their highest mean specific growth rate (Table 1) might shorten their vulnerability time to potential predators, presumably resulting in high survival in habitats with adequate food resources (see review by Helfman 1986). This temperature range (13-19°C) approximately coincides with the capture temperature range (14.5-

21°C) of our specimens in Tomales Bay.

Finally, food consumption and growth have leveled off in fish by 23°C, and their mean conversion efficiency is the lowest. The presumably higher metabolic costs at 23°C predict either increased foraging time, slower growth or both at these warm conditions.

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GAS SUPERSATURATION IN THE AMERICAN RIVER

John E. Colt
James M. Montgomery, Inc.
2375 130th Avenue NE, Suite 200
Bellevue, WA 98005

Kris Orwicz
Aquatic Biotics
14150 NE 20th Street, Suite 365
Bellevue, WA 98007

Dale Brooks
Animal Resources Service
School of Veterinary Medicine
University of California
Davis, CA 95616

Dissolved-gas supersaturation was monitored in the American River during 1982-1983 and 1985-1986. Dissolved gas levels during spring and summer were considerably higher than had been reported necessary to produce increased mortality due to chronic gas bubble trauma (gas bubble disease) in hatchery salmonids. The source of this gas supersaturation was from natural mechanisms: air entrainment, solar heating, and photosynthesis. During central California's major flood of February 1986, acutely lethal levels of gas supersaturation (200-240 mm Hg) were present in the American River and resulted in significant mortality of salmonid fishes at the American River and Nimbus hatcheries. The most probable source of this gas supersaturation was air entrainment at Folsom Dam. The impact of the high dissolved gas levels in hatchery water supplies was reduced with the installation of degassing structures in the raceway headworks.

INTRODUCTION

Dissolved-gas supersaturation can be a serious problem for aquatic animals under both natural and hatchery conditions. In rivers with extensive hydro-power development, air entrainment at spillways is a major source of acutely lethal dissolved gas levels to fishes during high flow periods (Weitkamp and Katz 1980). In the Columbia and Snake river basins, dissolved-gas problems have necessitated modifications to spillways (Smith 1974) and water releases (USACE 1986) to protect juvenile salmonids. The presence of large reservoirs can significantly increase both the magnitude and duration of downstream dissolved gas levels, even during non-spill periods. This may be due to the capture and retention of highly supersaturated water during the spring, and solar heating and photosynthesis within the reservoir.

Gas supersaturation (ΔP) was measured as the difference between total dissolved

gas pressure and the local barometric pressure (Fickeisen et al. 1975). The biological effects of a given ΔP depend on the depth of the animal in the water column, temperature, animal size and species, and nitrogen:oxygen ratio (Alderdice and Jensen 1985). Typically, a given ΔP will have a greater impact on fish in hatcheries than fish in open water due to differences in nutrition, longer exposure period, crowding, and shallow depth of most culture systems (Colt 1986). In a given river system, the level of gas supersaturation may show strong temporal and spatial variation. Information based on a small number of measurements may be highly misleading. Here we report our investigation into the seasonal variation of gas supersaturation in the lower American River in central California. The purpose of this study was to document the dissolved gas levels in the lower American and assess potential impact on fish under natural and hatchery conditions.

MATERIALS AND METHODS

The main fork of the American River is dammed in its lower portion by Folsom and Nimbus dams (river kms 46.6 and 33.0, respectively), and then flows into the Sacramento River at Sacramento (Fig. 1). Dissolved gas levels were generally monitored monthly during 1983 and 1985-86 at two locations: "hatchery" and "river". The hatchery site was in the headworks of the earthen raceways of the Nimbus Salmon and Steelhead Hatchery, which receives its water by gravity flow behind Nimbus Dam (Lake Natoma). The river site was monitored from the bank of the river below the dam, between the Hazel Avenue Bridge and the hatchery fish barrier. Dissolved gas data for 1982 were taken from Colt (1984*a*) for the river site and at Discovery Park, 32.5 km downstream. There was little difference in that study in ΔP between the "river" and Discovery Park sites.

Gas supersaturation was measured with an ES-2 "Weiss Saturometer" (ECO Enterprises, Seattle, Washington). The saturometer was immersed in the water up to the pressure gauge (about 1 m) and pumped every 2 min until a stable reading was obtained (25-30 min). Water temperatures and dissolved oxygen (DO) concentrations were measured using a DO probe (YSI Model 54RC) and calibrated based on values developed by Weiss (1970). Measured DO readings were corrected for pressure using the barometric pressure from the nearby NOAA weather station at the Sacramento Executive Airport. Preliminary flow data from the Fair Oaks gauging station (about 200 m below the river site) were obtained from the U.S. Geological Survey.

RESULTS

Gas Supersaturation in 1982, 1983, and 1985

During 1982, 1983, and 1985, the ΔP patterns were mixed: 1982 and 1983 patterns were relatively stable, while the 1985 ΔPs were stable during late winter-spring then declined from July through December (Fig. 2). The maximum ΔP occurred during the spring and early summer. Except for 1982 ($r^2 = 0.70$), the ΔP was not significantly

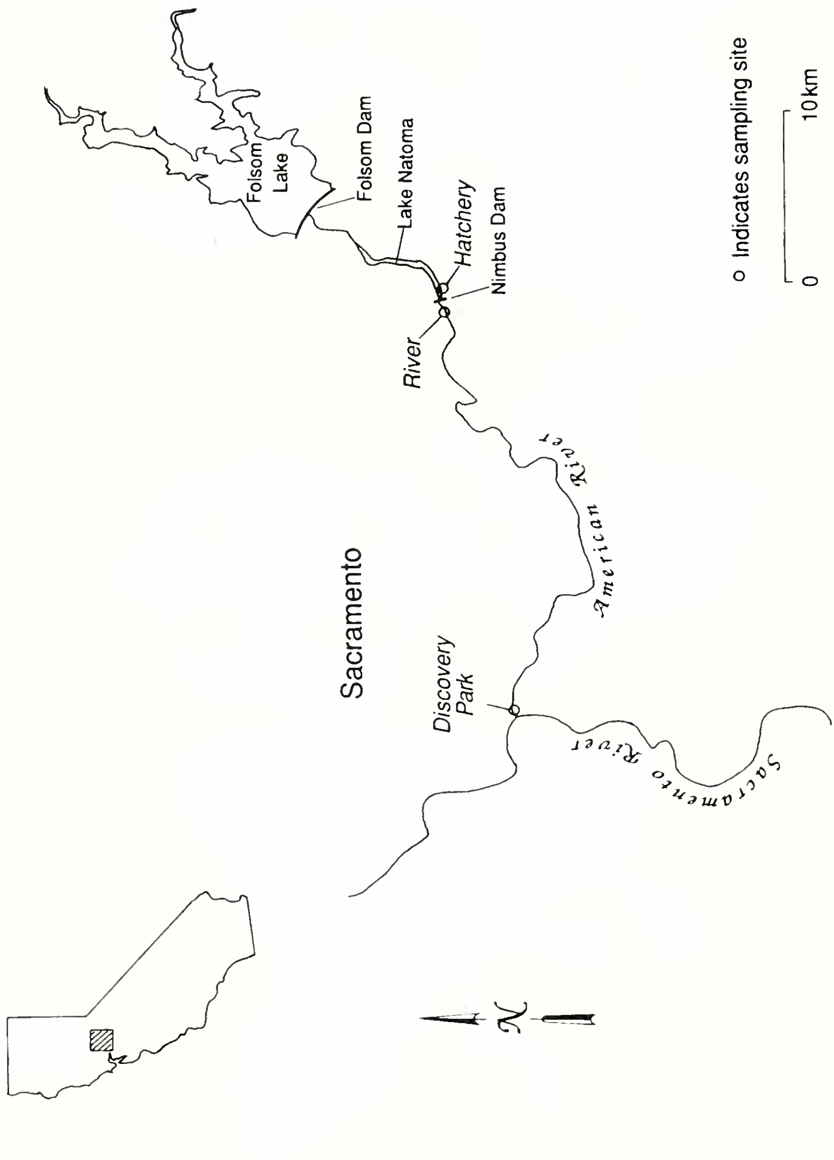


Figure 1. Map of study area showing locations of sampling sites.

correlated with either flow or temperature. The yearly maximum ΔP measured ranged from 58 to 94 mm Hg (Table 1).

Table 1. Maximum in the American River

Year	Site	Maximum ΔP (mm Hg)
1982	river/discovery	72
1983	river	94
1985	river	58
1986[a]	hatchery	237
1986[b]	hatchery	79
1986[a]	river	195
1986[b]	river	82

[a]Flow > 300 m^3/s
[b]Flow < 300 m^3/s

Gas Supersaturation in 1986 - Flood Period

A major flood event occurred in the American River basin in February 1986 (Fig. 3). During February of that year, the measured ΔP in the river and hatchery were very high (195 and 237 mm Hg, respectively). The highest ΔPs were observed at the highest water flow, although not enough data were available to develop predictive regression curves. Also, the effects of Nimbus Dam on river ΔP was not conclusive.

Gas Supersaturation in 1986 - Nonflood Period

The ΔP was relatively constant in the river and hatchery during April-June and decreased during July-December. ΔP was not significantly correlated with either flow or temperature in either the river or hatchery. In general, ΔP in the river was higher than in the hatchery during March-June (Fig. 2). The average temperature in the river was 0.2°C higher than in the hatchery during this same period.

DISCUSSION

Gas Transfer at Dams

The amount of air transferred into the water at a hydraulic structure depends on the velocity head of the jet into the tailwater, the shape of the jet, the basin length and depth, water temperature, initial dissolved gas level, and flow over the spillway (Johnson and King 1979). At a given dam, the ΔP resulting from air entrainment is typically a linear function of the spilled flow (D'Aoust and Clark 1980, USACE 1986, White et al. 1986). At very high flows, the ΔP-flow curve may flatten out or even decrease (Alderdice and Jensen 1985, USACE 1986) because of radical changes in the

Figure 2. Seasonal variation in the American River. Dashed line is the current USEPA criterion for fish of 76 mm Hg (total gas pressure = 110%).

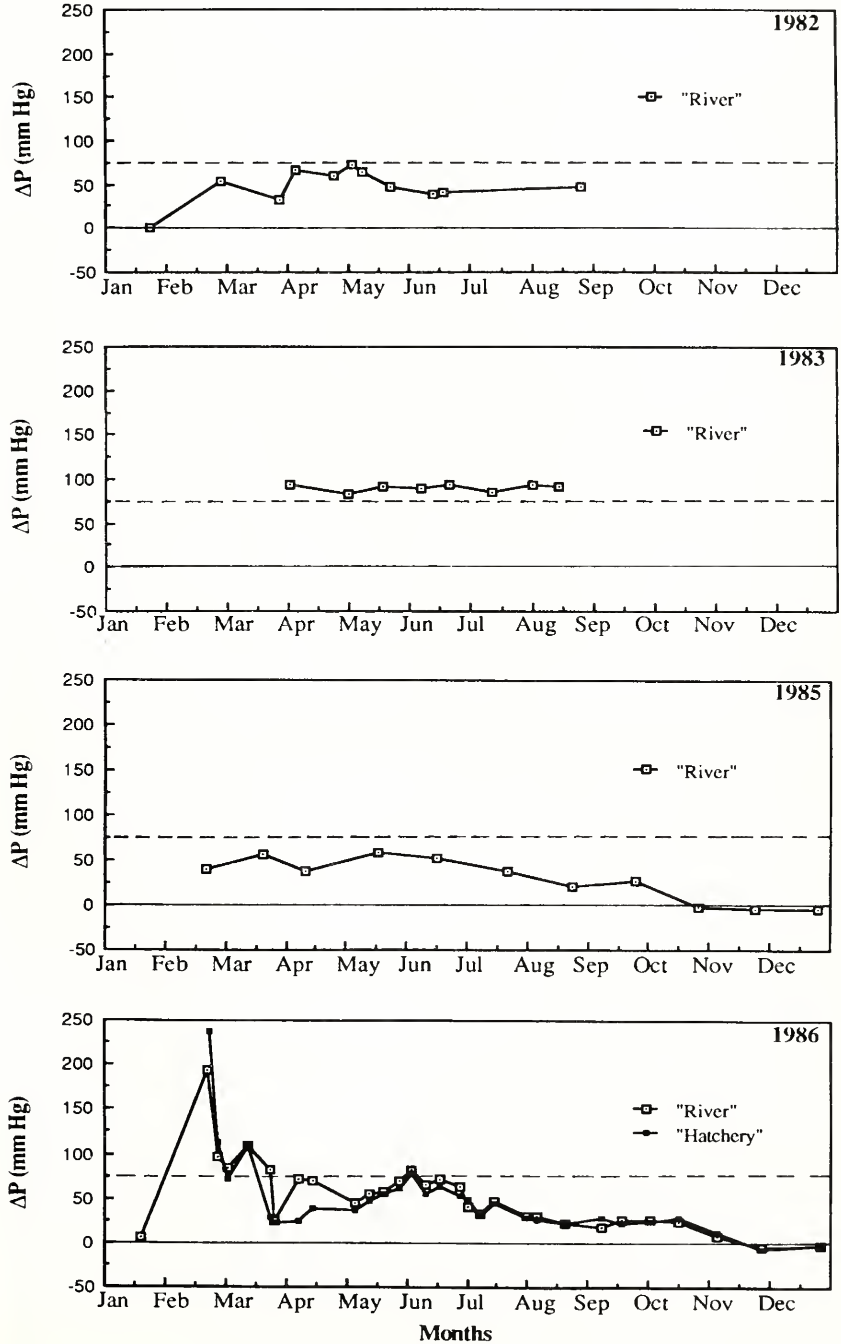
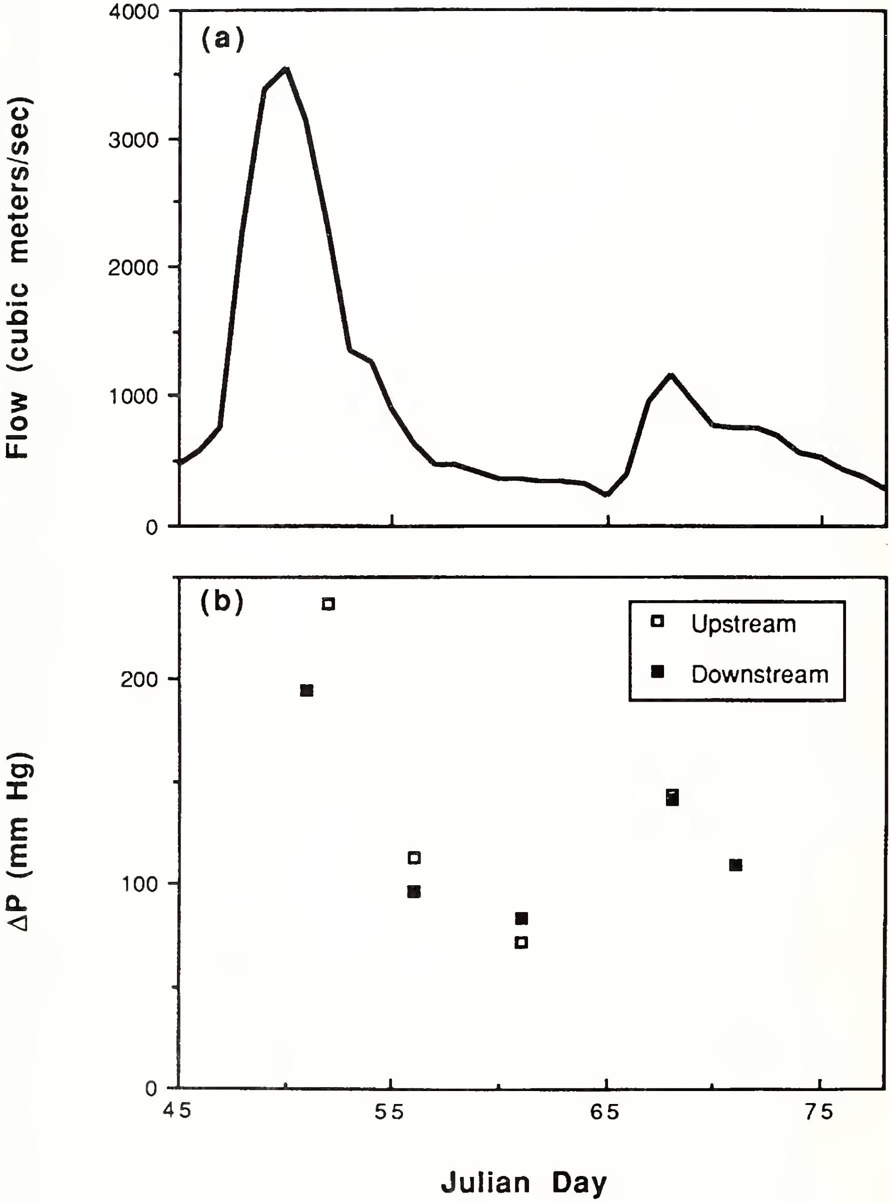


Figure 3. Variation of (a) mean daily river flow and (b) ΔP upstream and downstream of Nimbus Dam during the 1986 flood.



flow patterns over the structure. For a given flow, a higher ΔP will result from higher dams due to greater jet velocity. At dams with several types of spillways, the resulting ΔP will depend strongly on the type of spillway(s) being used (White et al. 1986). The variation of ΔP with water flow in the American River showed the characteristic positive slope, but not enough data were collected during this relatively brief event to adequately define the curve.

Gas Supersaturation Potential of Lower American River

The hydraulic height of Folsom Dam is 82 m compared to 14 m for Nimbus Dam (USDI 1981). Therefore, the potential for dissolved-gas entrainment at Folsom Dam is probably greater than Nimbus due to its higher hydraulic height and resulting higher jet velocity (Roesner and Norton 1971, Johnson and King 1979).

The dissolved gas entrained in a series of dams such as Folsom and Nimbus dams will depend on the following factors for each dam: (i) influent dissolved gas concentrations, (ii) hydraulic height, (iii) type of spillway(s), and (iv) turbine capacity.

The turbine capacity at Folsom (217 m^3/s) is greater than at Nimbus (133 m^3/s) (USDI 1960*a*, 1960*b*). Folsom Dam has two types of spillways: eight gated ogee (12.8 m wide X 15.2 m high) and eight curved sluices (1.5 m wide x 2.4 m high) located in the spillway section (USDI 1960*a*). The sluices are used to regulate flows < 895 m^3/s. Spill flow > 895 m^3/s is passed over the ogee spillways. The jet angle of the sluices is much shallower than the ogee spillways, and as a result, may produce less gas supersaturation per unit flow. The use of these two different types of spillways may tend to reduce the amount of entrained gas released from Folsom Dam during low flows compared to the potential from the 18 radial-gate spillways at Nimbus (USDI 1960*b*).

Depending on the river flow, four different spill flow regimes are possible (Table 2). The observed change in ΔP as the water flowed over Nimbus Dam is due to the complex interactions of the differences in hydraulic heights, turbine capacities, and spillway characteristics of the two dams and the upstream gas conditions. A continuous gas monitoring system at a minimum of four points on the lower American River would be needed to fully document the gas entrainment characteristics of this developed river system.

Both the American River and Nimbus hatcheries obtain their water upstream of Nimbus Dam, and, therefore, hatchery fish are exposed to high dissolved gas levels

Table 2. Potential flow regimes affecting dissolved gas levels below Nimbus Dam, American River, California.

	Dam spilling?	
Flow (m^3/s)	Folsom	Nimbus
<133	no	no
134-216	no	yes
217-895	yes - curved sluices	yes

during high water flows. The presence of dams on the American River probably has had a significant effect on gas supersaturation even when water was not being spilled due to a number of mechanisms. During the spring, the ΔP of the water filling the reservoir may be as high as 65 mm Hg (Colt 1984*a*), probably due to natural air entrainment in streams. Thus, Folsom Dam captures this supersaturated water and releases it over the next 6 months, or more. Assuming that Folsom Reservoir was filled in 1986 with saturated 12.1°C water in February, solar heating to 15.8°C in June could produce a $\Delta P = 59$ mm Hg if no gas transfer occurred (Colt 1984b). Photosynthesis may also tend to increase the ΔP, especially in Lake Natoma due to its shallow depth. The slow decrease in ΔP during the summer was probably due to biological oxygen consumption that reduced the partial pressure of dissolved oxygen and due to increased degassing of nitrogen in the river as flow decreased. The lack of a consistent significant linear correlation between ΔP and temperature or flow is a result of these five complex mechanisms operating simultaneously.

The longest period of high ΔP during summer months occurred in 1983, a year with 234% of normal annual runoff (Fig. 2). During this year, the ΔP exceeded 76 mm Hg for at least 4.5 months. In contrast, following the flood in 1986 (79% of normal annual runoff), only one measurement exceeded 76 mm Hg. The variation of maximum yearly ΔP in the American River during non-flood conditions may be influenced by the ΔP, temperature, filling rate of Folsom Reservoir, rate of temperature increase in the reservoir during the spring, biological oxygen demand in the reservoir, and reaeration in river. Additional research is needed to better identify the significant mechanisms that account for both the seasonal and year-to-year variation.

Effects of Gas Supersaturation in the American River

The present United States water quality criterion for gas supersaturation is 110% total gas pressure (TGP) or $\Delta P = 76$ mm Hg (USEPA 1976). On a chronic basis, ΔPs in the range of 30-40 mm Hg can result in increased mortality of fish in hatcheries and shallow rivers (Cornacchia and Colt 1984, Alderdice and Jensen 1985, Wright and McLean 1985).

Significant mortality of salmonids occurred in the American River and Nimbus hatcheries during the flood period of 1986 (R. Ducey, Calif. Dept. Fish and Game, pers. comm.). While final hydrologic analysis of this flood has not been completed, it was a relatively rare event with a reoccurrence interval greater than 100 years. A perforated horizontal screen was installed at the exit from the headworks, so the water flowed over and through the screen as it entered the raceway. It has been the observation of hatchery personnel (R. Ducey, pers. comm.) that river flows greater than 1,000 to 1,500 m^3/s will produce clinical signs of gas bubble trauma in the hatchery. Using a critical value of 1,000 m^3/s, the last 22 years of stream flow data for Fair Oak gauging station were reviewed. There were 5 events that exceeded 1,000 m^3/s for at least 4 days and 12 events that exceeded 1,000 m^3/s for 2 days. These events were unevenly distributed over the reviewed time period, with the greatest frequency occurring during 1964-1970 and 1979-1986. Based on this flow data, the yearly

probability of gas bubble trauma problems may range from 0.23 to 0.77.

In the Columbia River Basin, elevated dissolved gas levels have been controlled by the addition of "flip-lip" spillway deflectors (Smith 1974), continuous monitoring and telemetry of dissolved gas levels on a real-time basis, and forecasting of dissolved gas levels and scheduling of spilling to control dissolved gas levels (USACE 1986). The impact of gas supersaturation could be reduced by installation of more efficient degassing systems at the hatchery (Colt 1986).

Gas supersaturation in the American River showed a characteristic seasonal change as well as significant year-to-year variation in the maximum level and duration of high ΔP. The presence of Folsom and Nimbus dams probably have a major influence on gas supersaturation in the lower American River.

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NORTHERN RANGE EXTENSION FOR THE SQUARESPOT ROCKFISH, *SEBASTES HOPKINSI*

DANIEL L. ERICKSON, ELLEN K. PIKITCH, AND JAMES WILDER ORR
Fisheries Research Institute, School of Fisheries, WH-10
University of Washington, Seattle, WA 98195.

A squarespot rockfish, *Sebastes hopkinsi*, was collected on 8 December 1989 off the southern Oregon coast (lat 43 degrees 1.0 min N, long 124 degrees 51.8 min W) by the *WESTERN SEAS* (skippered by Jimmy Burns). The previously listed range for this species was the Farallon Islands (off San Francisco) to central Baja California (Eschmeyer et al. 1983); hence, this collection represents a northern range extension of approximately 590 km. The specimen, a 215 mm standard length mature female, was captured using commercial bottom trawl gear fished at a depth of 115 m over hard bottom and pinnacles. Other species captured at this site were widow rockfish, *Sebastes entomelas*; rosethorn rockfish, *S. helvomaculatus*; shortbelly rockfish, *S. jordani*, canary rockfish, *S. pinniger*, redstripe rockfish, *S. proriger*, pygmy rockfish, *S. wilsoni*, sharpchin rockfish, *S. zacentrus*, lingcod, *Ophiodon elongatus*, Pacific halibut, *Hippoglossus stenolepis*, and spiny dogfish, *Squalus acanthias*.

The specimen agrees well with the descriptions of Cramer (1895), Jordan and Evermann (1896), and Phillips (1957). It possesses the distinctive color pattern of *S. hopkinsi*, including a dusty tan body with a series of four squarish dark-brown blotches along the lateral line. Other significant counts and characters include the following: D XIII,15; A III,7; Pect. 17; LLp 54; GRt 37(11+26); second anal spine extending beyond the third; anal fin with posterior slant; nasal, preocular, supraocular, postocular, tympanic, and parietal head spines weakly present; interorbital space convex; preopercular spines strongly directed posteriorly; lower edge of gill cover smooth, spines absent; posterior edge of maxilla terminating at anterior edge of orbit; mandible scaled; small ventrally directed symphyseal knob present. This specimen is deposited in the University of Washington Fish Collection at the School of Fisheries (UW 21426).

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FIRST RECORD OF MOZAMBIQUE TILAPIA IN THE SAN JOAQUIN VALLEY, CALIFORNIA

TIM HEYNE, BERT TRIBBEY, MATT BROOKS, AND JENNIE SMITH
White Bass Project, Department of Biology
California State University
Fresno, California 93740-0073

Two cichlids were seined from a mud-bottomed pond in Lake Success, Tulare County on 30 August and 4 September 1989 (Fig. 1). The pond forms within Kencade Cove when the water in Lake Success drops to low levels. The fish were captured with an 18-m beach seine (12 mm mesh). Both fish appeared to be in good health.

Total lengths, after preservation in 95% ethanol, were 86 mm and 120 mm. The cycloid scales lacked annuli but averaged 50 and 60 circuli, respectively. Scale counts of the lateral lines were 31 and 33, respectively. The dentary teeth of our specimens were compared with those of fishes in the California Academy of Sciences. *Tilapia mossambica* and *T. zilli* were chosen for comparison because they are known to occur in California (Moyle 1976). Our specimens' teeth were very similar to the spatulate teeth of *T. mossambica* and quite different from the peg-like teeth of *T. zilli*. Complying with recent changes in nomenclature, we assigned the name *Oreochromis mossambicus* (Trewavas 1983) to our specimens.

An established population of *O. mossambicus* was first reported in Imperial County, California in 1966 (St. Amant 1966). Mozambique tilapia have been thought to occur only south of the Tehachapi Mountains. How these fish were introduced to the San

FIGURE 1. A 120 mm (TL) cichlid captured at Lake Success, California 30 August 1989. Photo by D.L. Chesemore.

Joaquin Valley and whether they will become established are important but unanswered questions. It is hoped that establishment in Lake Success will be halted by low water temperatures in winter (Trewavas 1983).

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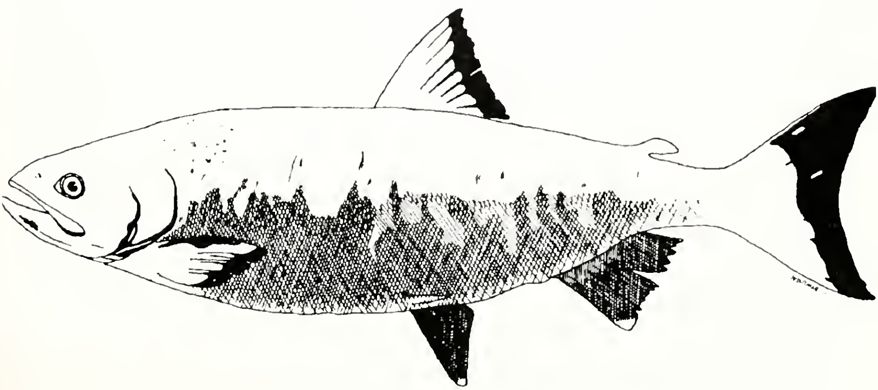
PARTIAL XANTHISM IN AN ADULT CHUM SALMON, *ONCORHYCHUS KETA*, NEAR CHIGNIK, ALASKA

GREGORY T. RUGGERONE
Fisheries Research Institute
WH-10, University of Washington
Seattle, Washington 98195

A partially-colored, adult chum salmon, *Oncorhynchus keta*, was captured by the purse seiner F/V *Dreamer* on 20 July 1988 near Chignik on the Alaska Peninsula (lat. 56° 30' N, long. 158° 05' W). Approximately 50 chum and 50 sockeye salmon, *O. nerka*, were captured in the seine haul. While in the purse seine, the unique salmon remained near the surface rather than sounding to the bottom of the net with other salmon. The fishermen noted that the partially-colored fish appeared strong and healthy, and was similar in length to the other chum salmon (ca. 70 cm total length) but was slightly thinner. After photographing the fish, they released it to spawn in a nearby stream.

The chum salmon displayed partial xanthic coloration, as do many fishes that have a heterozygous gene causing color dilution (Wright 1972) or some other developmental anomaly. The chum salmon was unusual among partial xanthic fishes because it was bright yellow above and normally colored below the lateral line (Fig. 1). Most partial xanthic fish have splotches, streaks, or bilateral pigmentation, although Blackett and Armstrong (1965) reported a Dolly Varden char, *Salvelinus malma*, that had increasing pigmentation with distance from the ventral area. The pigmented area below the lateral line of the chum salmon was silver and grey, and had faint "water streaks" that are typical of maturing chum salmon in coastal waters. The head was mostly yellow but the eyes were normal in coloration. Unusual black pigments were present on the trailing edges of the dorsal, pectoral, and caudal fins, whereas it had white tips on the

Figure 1. Drawing of the partially colored chum salmon captured near Chignik, Alaska. Areas without lines were bright yellow; areas with lines were the typical silver-grey color of chum salmon. The drawing was based on several color photographs.



pelvic and anal fins, typical of maturing chum salmon.

Xanthism and albinism in adult fishes are rarely observed in nature (Gartner 1986). Factors involving predation, mate selection, viable offspring, avoidance by prey and solar radiation tend to select against the survival of these fish (Dunham and Childers 1980). Dr. E. O. Salo (University of Washington, Seattle, pers. comm.) observed xanthism in a few chum fry of wild and hatchery origin, but never observed it in adult salmon. Xanthism, albinism, or partial coloration of wild adult salmon have not been previously reported. Unlike most pelagic fishes, the partially-colored chum salmon had reverse countershading which seems to be disadvantageous when encountering predators.

Photographs and descriptions of the fish's behavior were kindly provided by K. Astor, C. Astor, and H. Munson. The fish was drawn by E. Warner, and constructive comments on the manuscript were made by W. Hershberger, R. Lea, T. Quinn, and E. Ueber. Funding for the preparation of this note was provided by National Marine Fisheries Service and the Chignik fishing industry.

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EDITORIAL NOTE

A university professor would occasionally remark that "There is nothing new under the sun." In that regard, the following article by Joseph Grinnell is reprinted from the first issue of *California Fish and Game* in 1914. Grinnell was one of the most notable naturalists/ecologists/zoologists of his time (and ours) and is credited with having a guiding influence on present day wildlife ecology. His article evaluates bird life as an asset to mankind. In doing so, he directly or indirectly addressed topics of current interest and importance such as: species preservation, intrinsic values of wildlife, conservation biology, competition among species, and educating children and adults on the value of wildlife. His article is reprinted to illustrate the value in looking back to address questions of the present and whether work so recommended and needed in years past has been accomplished. This and other noteworthy articles from the early volumes will be reprinted as space permits —*Eric R. Loft, Editor in Chief, 1991.*

Calif. Fish and Game 1(1):20-22 1914, (Reprinted in 77(1):57-60)

BIRD LIFE AS A COMMUNITY ASSET

Joseph Grinnell
Museum of Vertebrate Zoology
University of California
Berkeley, California

Students of natural history have become fully aware that as the country is settled marked changes take place in its bird life. A few of our species, such as the linnet and mockingbird, have become more numerous than they were in the early days. But very many more have become noticeably scarcer; some have disappeared altogether. Bird life as a whole has diminished in quantity to an alarming degree.

Those who have made a scientific study of our bird life have come to the conclusion that it has a distinct value to human interests. This value consists first of all in the well established economic bearing of birds upon agricultural interests; 90 per cent of our birds occupy an important position in maintaining the balance of nature, by which they serve to check abnormal increase in plant-eating insects and excessive multiplication of weeds.

Then there is the dollars-and-cents value of game birds - not in their market value, because we believe that market hunting will soon be a thing of the past- but because their pursuit, whether by the shotgun exponent or camera hunter, involves large commercial dealings through transportation and equipment. It is believed that a very large value pertains to bird life as an object of pursuit for whatever purpose, because this pursuit leads to wholesome pleasure and hearty outdoor exercise on the part of many people who otherwise live sedentary lives.

There is, again, that refreshment to the mind resulting from contemplation of birds as possessors of pleasing form and plume, cheerful manner, and attractive song. This brings an active appreciation on the part of the majority of mankind. In this role, birds at large have an important esthetic value.

Another point to be considered is the principle that to allow complete extermination of any living thing is out of harmony with an enlightened consideration of the future. Our successors will not approve of our thoughtlessness in completely destroying the California condor any less than we deplore the wanton destruction of the great auk by our ancestors. In other words, it is now generally recognized as ethically wrong to jeopardize the existence of any animal species.

Yet one more value of bird life, and one which I urge as being worthy of most serious consideration, namely, the inherent value of birds in educational work with children. We hear nowadays of all sorts of systems- the Montessori, for example- which are designed to hasten the development of alertness and precision in exercising the senses. Can any objects be better adapted for just such purpose than birds- with their multifarious colors and color patterns, their variety in form, their quickness and peculiarities in movement, their range of voice. And, of all the systems of early education, this is the primitive one, the one most in accord with the normal development of the child, because of long standing, ancestrally.

When we come to weigh together all these valuations- economic, esthetic, educational- is there justification for anyone's claiming that attention to conservation of bird life is of trivial importance? Is this subject not most emphatically worth the consideration of thrifty, busy people?

I must insist that conservation of bird life is of equal import with that of any of our other natural resources. It is dollars-and-cents economy, not only to stop waste but to take steps to maintain an optimum of value as regards this asset- in other words, to maintain a large principal, upon which an undiminished income can be realized as time goes on.

What steps are to be taken to keep our bird population so that it may serve its highest usefulness to mankind? I believe that it is feasible to maintain it, and I am not arguing from a sentimental standpoint, either, but from a utilitarian standpoint.

Some of the factors correlated with the settling up of the country, and which are adverse to the persistence of an abundant native bird population are- first, in my opinion, the ravages of the house cat. No matter how well fed your tabby may appear, she is by nature a nocturnal marauder, gifted through keenness of hearing, eyesight, scent, and unquenchable instinct to search out and destroy young and old birds. I am confident that an enormous annual tool upon bird life is our suburban districts is exacted by the house cat. In the country, where it is well known that many cats have gone wild, they constitute a big factor against the birds. There is abundant proof to support this assertion in the experience of those of us who tramp the hills and bottom lands in quest of facts and laws of wild life interrelationships.

The second most important factor over a large part of the country is the invasion by the English sparrow. This interloper appropriates food and shelter rightfully belonging to native birds, and sooner or later crowds them out. Southern California is now in a critical period, in that the English sparrow has but recently arrived. If we are to prophesy subsequent history from that which has been repeated over and over again in the eastern states as this bird traveled from east to west, we are doomed to be overrun by English sparrows, unless drastic measures against them to be taken at once. Now, while they are still few in numbers, is the time to combat this nuisance effectively.

A third factor is the reduction in food supply due to the reclamation and cultivation of wild lands. This affects our native species of birds inevitably, but it can be counterbalanced to a considerable extent by the use of ornamental shrubs and garden flowers of such kinds of plants as will produce suitable food for the birds. The fourth factor against the birds is the thoughtless destruction of them, for fun, as by the not infrequent gunner who shoots swallows and swifts because they afford a favorable target; to eat, as by the Italian immigrant, who sees in the smallest bird simply its value as a mouthful of food, to be netted or shot in as great numbers as possible; and by the uninstructed small boy, who robs bird's nests far and wide merely for the exhilaration of discovery and appropriation. Lastly, the exploitation of birds for commercial purposes, to be sold in the market as food, or worse yet, so that their feathers may serve to adorn hats- still exists to a much larger extent than many of our citizens suppose. The lure of the dollar justifies any means to obtain it that can be devised on the part of certain unthinking members of society. It may not be that the wings of the terns

destroyed along our beaches are used in millinery here. They may be shipped to London and used there as "foreign" birds. But we, in our turn, are catering to bird destruction somewhere else if we buy in our local millinery stores plumes, or wings, or feathers of so-called "foreign" birds.

Every one of the above adverse factors is such as can be either eradicated entirely or can be mitigated to a very large degree. The cat question must be solved by the licensing and control of pet cats and the extermination of homeless ones- precisely the same treatment which is now accorded the dog in most of our cities.

The English sparrow must be dealt with systematically and rigorously. Call the English sparrow a foreign weed, if you will, the undue spread of which must be continually fought. We maintain an army of caretakers along our streets and in our parks so that the attractive flowers and shrubs are not choked out. It is not exactly as good sense to maintain one or more properly qualified employees in each city to see to it that by trapping or shooting or poisoning- whichever method proves most effective- the English sparrow population is kept down below the point where it is distinctly deleterious to our native birds, even though complete extermination of the pest may never prove possible? The diminution in natural bird food and disappearance of springs can be compensated for privately, and publicly as in parks, by providing food and watering places, just exactly as a lawn or a flower bed may be supplied at regular intervals with concentrated fertilizers, and daily sprinkled. To my mind, the attractiveness of our bird life- in other words, the esthetic feature in its value- warrants consideration for the same reasons as the flower garden. Care and attention must be bestowed on both.

Finally, to lessen or remove the factor of thoughtlessness, or ignorance, or commercialism, we have state and federal regulations. These are, at the present time, approaching the ideal. We need, and for the most part now secure, conscientious enforcement of this legislation on the part of our officers of the law. But efforts toward enforcement have often been observed to be futile unless the people at large have been led to see the wisdom in these laws. Hence, we must have popular education as to the features and value of our bird life. One natural channel for such education, by which adults as well as children are to be convinced of the facts in the case, is the school, where bird study should be incorporated as an essential element in the grade curriculum.

Our bird life is a valuable public asset and deserves sane consideration as such.

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INSTRUCTIONS FOR CONTRIBUTORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish, wildlife, and native communities. Original manuscripts submitted for consideration should deal with California flora or fauna, or provide information of direct interest and benefit to California researchers and managers.

MANUSCRIPTS: Refer to the CBE Style Manual (5th Edition) and a recent issue of *California Fish and Game* for general guidance in preparing manuscripts. Specific guidelines are available from the Editor in Chief.

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